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The Institute of British Foundrymen
The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Contents

	PAGE
Alloy Cast Irons	413
Making History	413
The British Foundry School	414
Correspondence	414
Works Costing System	414
Making a Propeller by Snap-Flask Methods	415
Corrosion of Tin and Other Metals by Insulating Oils	415
Heat Absorption in Tensile Tests	415
Trade Conditions in the Netherlands East Indies	416
Welded Steel Bedplates Applied to Large Gear Units	416
Welded Mild-Steel Drums	416
The Influence of Special Elements on the Physical Properties of Cast Iron	417
Technology of Cast Light Alloys and Their Application in Motor-Car Construction	420
Useful Hints on Income Tax	420
The Heat Treatment of Cast Iron	421
Rustless Steels in the United States	423
Large Universal Grinding Machine	424
Creep Properties of Cast Iron	426
Students' Corner	428
This Week's News in Brief	430
Raw Material Markets	432

Alloy Cast Irons

During recent years there has been marked progress in the development and use of alloy cast irons. The progress made with such irons has resulted from a large amount of research and investigation, from developments in foundry technique, and from methods of treatment, and has provided materials the properties of which have in some cases more than justified their additional cost.

The properties of cast iron which have been enhanced by the addition of alloying elements have been strength, hardness, heat resistance, and corrosion resistance. There are other properties, however, which have been influenced by alloy additions, such as thermal and electrical conductivity, thermal expansion, and magnetic properties, which are of the utmost importance when cast iron is to be used for certain purposes, and which have to be considered by designers and users.

In the internal-combustion engine, cast iron is still largely used, especially in the heavier units, for such parts as cylinders, cylinder heads and pistons, and any improvements in the strength, hardness, or heat resistance of the material, whether by alloying or heat-treatment, have got to be seriously considered, particularly as progress is still being made in the development of this prime-mover. Apart from these properties, the suitability or otherwise of material for a piston depends on its thermal conductivity and co-efficient of thermal expansion for reducing heat stresses, and is one of the reasons why aluminium alloys have largely replaced cast iron for such purposes. In considering the use of alloy cast iron for piston material, therefore, these properties have to be reckoned with, and it is to the engineer's advantage that in alloy cast irons with small additions of nickel and chromium neither property is seriously affected and full use can be made of the additional strength and heat-resistance properties without unduly increasing heat stresses. Where alloy additions with or without heat-treatment, however, produce an austenitic structure in cast iron, accompanied by a low thermal conductivity and a high co-efficient of expansion, a serious disadvantage arises and limits the application of such material for certain parts. For other parts, however, austenitic cast irons have a definite value in modern engineering design and construction. In the Mahle composite piston, for example, austenitic cast irons have been found on account of their high co-efficient of thermal expansion to be more suitable for piston-ring groove inserts than ordinary cast irons. Other examples where cast iron and aluminium alloys are used together and where, by using austenitic cast iron, advantage is gained, might also be cited. Austenitic irons with high nickel content have also been made in which the thermal expansion property is reduced to a minimum, and ought, therefore, to find application for parts where low expansion properties are required.

The development of cast irons with definite magnetic properties has also proved of value to the electrical industry. The use of castings with such properties is to be preferred to fabricated steel parts, which, although they may be less expensive, show large magnetic losses due to joins and welds. On account of their non-magnetic properties, austenitic cast irons have proved of considerable use for switch gear, and other alloy cast irons with high electrical resistance have been found useful in generator castings in reducing eddy currents.

Making History

The times we live in are anxious and exciting, and a few generations hence we shall look back on them as an outstanding period in world history, but it is very difficult in the press of daily business and the preoccupation with domestic and personal affairs to see the wood for the trees. Our newspapers are the best informed and most impartial (the best of them) in the world, but sometimes it is a good plan to read something which gives not only the things the newspapers do not give, but which provides also the continuity between events which make them emerge as trends in the making of history. The thought came to us when we met a well-known foundryman in a railway carriage deep in a serious book quite unconnected with founding. So we think that many whose tastes go beyond the detective story (excellent as that is in its place) will appreciate a recommendation to read three books which have been published in the last few months. They have little or nothing in common beyond the fact that they are all recently written, are all by observant American journalists, and all deal with contemporary history. Mr. Negley Farson's "Way of a Transgressor" must have earned for him a small fortune already. An American business man, he became a journalist in order to tell Americans the strange happenings in Europe, till he was fired for becoming too English, and hence not detached enough from European affairs. Before that he spent a kind of apprenticeship at a well known works near Manchester, and then went to Russia, saw several years of the war time struggle from the Russian side, joined the R.A.F. as a "Canadian," and then spent a number of years in journalism proper. Intensely readable,

(*Concluded on page* 415.)

The British Foundry School

In our issue of October 24, 1935, we outlined the constitution of the British Foundry School and its governing body. The School opened for its first session in October, 1935, and a course of one year's instruction is provided. The total number of students taking the course for the first year is thirteen and they are now in their final term. During the year they have had lectures from the Lecturer-in-Charge, Mr. J. Bamford, B.Sc., on foundry practice and foundry metallurgy, and on physics and chemistry from members of the permanent staff of the Birmingham Central Technical College. In addition, about one hundred and twenty lectures have been given by specially selected specialists of national reputation in their particular subjects. Visits have been paid each week to foundries and laboratory and practical instruction is a feature of the course.

The examination for the Diploma will take place in July and a number of distinguished authorities and specialists have been appointed as assessors in connection with this examination. It is anticipated that the Diploma will receive the endorsement of the Board of Education.

Finance

As has been previously explained, the School is supported financially by a group of trade associations, technical institutions and research associations in the industry, who contribute approximately £200 per annum. In addition to the list previously given, the School is now supported financially by the City and Guilds of London Institute. Enough to make this up to £500 per annum is required from the industry, and if this is obtained the whole of the balance of the expenditure, apart from receipts from students' fees, is provided by a grant from the Board of Education. The following amounts have been received since the list previously published:—

	£	s.	d.
Alldays & Onions, Limited, Birmingham	3	3	0
Archibald Kenrick & Sons, Limited, West Bromwich	5	0	0
Electric Construction Company, Limited, Wolverhampton	10	10	0
Newton, Chambers & Company, Limited, Sheffield	5	0	0
Hopkinsons, Limited, Huddersfield	10	10	0
Alfred Herbert, Limited, Coventry	5	0	0
Worthington - Simpson, Limited, Newark	10	10	0
British Piston Ring Company, Limited, Coventry	2	2	0
Ferranti, Limited, Hollinwood	5	5	0
A. Reyrolle & Company, Limited, Hebburn-on-Tyne	5	5	0
Bristol Aeroplane Company, Limited, Bristol	2	2	0

The £500 required from these various industrial sources for the first year has now been obtained.

Session 1936-37

Entries for the next session, 1936-37, can now be received. Application forms may be obtained from the Secretary of the School, Central Technical College, Suffolk Street, Birmingham 1, or from Mr. J. G. Pearce, Honorary Treasurer, 21-23, St. Paul's Square, Birmingham 3. The fee for students is £30 for the session. In the majority of cases students for the first year were nominated by interested firms who wished to provide promising men with opportunities for receiving the highest instruction available in founding, instruction at least as good as that available in the highly specialised schools in founding of France and Germany.

It is anticipated that the first Annual Meeting of the School will be held in July, to which all subscribers and others interested will be invited, and a full statement of accounts and activities will be available.

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

All-Round Prices

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—I have read with much interest your leader "Level Pegging," and hope that most of its contents are true, as, if so, it will have the effect of improving conditions in foundries generally. I do not wish to enter into any controversy as I have not much spare time, but if you could see your way clear to put before all concerned the ruinous and idiotic practice of buyers insisting, and foundries supplying, castings of all classes at "all-round" prices, you would save some buyers from being dismissed and many foundries from bankruptcy.

There are buyers who purchase pig-iron, steel, and the like, who tell foundry salesmen that they have not paid a bean more for anything, and do not intend to pay increased prices for castings, and to-day numbers of foundries are being brow-beaten and frightened out of putting forward legitimate increases in price. On the other hand, when one sends inquiries to the firms who employ smart buyers for their own latest sale prices they do not hesitate to quote the highest prices with the definite reason that the increase is due to rises in wages and raw materials.

The cost of moulding per cwt. of castings can vary from 1s. to 20s., and for buyers to ask any foundry to quote all-round figures is absurd. There can be only one reason for the buyer to demand such prices, and that is to rob the founder, and the only reason that foundrymen quote them is that they have no idea of costs, their foundries being so broken down and filthy that they could not get a costing system to operate in their works. I know of foundries where the roofs are so bad that in the winter men have been trying to make moulds in snowdrifts, and the yards are so bad that they keep rubber waders for visiting buyers to get round the works in an endeavour to locate castings, yet under these conditions, because the price is cheap, the buyer will place orders with such firms. There is another feature which is responsible for the foundry getting a bad name, and this is due to foundrymen quoting prices with no knowledge of a job and then finding out by the scrap return that it is a loss, with the result that they stop manufacture and hold up deliveries, and eventually the purchaser has to move his patterns, or look for other methods of manufacture.

Engineers do not sell their products at so much per cwt. Of two machines weighing exactly the same one may cost ten times more than the other, both machines being made of similar materials. If it were pointed out to the engineer that they were both made of grey iron and why the prices should vary, he would treat the remark with the contempt it deserved; but the engineer will let his buyer insist on all-round prices for castings, so is it not time that Mr. Engineer gave his buyer some idea of business and not so much of the "Dick Turpin" proposition?

I do hope you will endeavour to get the idea of prices per piece more firmly established.—Yours, etc.,

"TORQUEMADA."

May 11, 1936.

SHEFFIELD JUNIOR TECHNICAL SCHOOL, which was established three years ago, has now 70 students trained to enter industry. This training fits the students to become capable and skilled craftsmen in the steel trade, and some of the steelworks have already interested themselves in the boys who will leave the school in July. It is hoped many of the big steel concerns will offer careers to these ambitious young men.

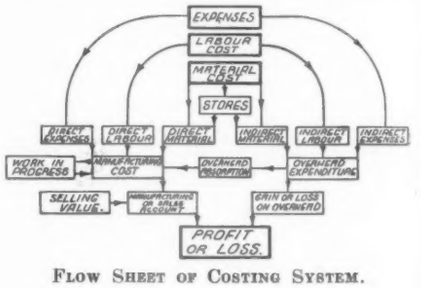
Works Costing System

Following the recent correspondence by Mr. David Brown on the subject of "Uniform Costing," which was initiated by the Interim Report of the Costing Sub-committee of the Institute of British Foundrymen, there have been requests made that the methods used by David Brown & Sons (Hudd.), Limited, should be published. The following brief description gives the outline of the system which will more readily be understood by referring to the accompanying diagram, which has been prepared on the lines of a "flow sheet."

Code numbers, used for the classification of customers' orders and overhead charges, are arranged as follow:—1 to 99, departmental; 100 to 999, stock and cost control; 1,000 to 9,999, overhead charges (a number is provided for each class of expense); 10,000 to 99,999, stock manufacture orders; 100,000 to 999,999, sales, orders, further sub-divided by commodities.

Labour Cost.—Attached to each drawing issued to the works is a planning sheet giving details of the operations for the particular job concerned and the time allowed for each operation. Each man is supplied with a time sheet twice weekly on which he enters the date, machine number, order number (one of the five- or six-figure order numbers listed above), job number, operation number, time started, time finished and time allowed. In the case of machine repairing, labouring, crane driving, etc., a time sheet is made out indicating the job number or labour classification, the appropriate overhead charges code number and departmental number being inserted by the cost office.

When the time sheets have been checked, the total number of hours allowed against each sales order is extracted by means of tabulating equipment. Rates per hour, for direct labour and overhead, based on



FLOW SHEET OF COSTING SYSTEM.

allowed time, have been established for each commodity and vary for the different sizes. The total time allowed for an order extended at the appropriate rate gives the total cost of direct labour and overhead. The indirect labour costs against the overhead numbers for each department is then extracted from the time sheets.

Material, etc.—The cost against each sales order and against each overhead number for the different departments is obtained on the tabulating equipment. The items dealt with under this heading include purchases, material from stores, depreciation, electricity, rates, taxes, insurances, etc.

Overhead.—The indirect labour and material, etc., against each code number is summarised departmentally, totals being obtained for each department and for the works as a whole. The absorption figure is obtained by deducting the total direct-labour amount from the combined total direct-labour and overhead amount. The difference between the overhead expenditure and absorption amount represents the gain or loss on overhead.

Manufacturing Profit.—Summaries are prepared showing the total cost of direct labour, overhead and material, etc., for the four-weekly period plus the work in progress at the commencement of the period for each order. The cost of sales is obtained by taking the whole or a portion of the cost against orders which are wholly or partly delivered. The difference between the cost of sales and the selling value represents the manufacturing profit.

Total Profit.—This figure is obtained by combining the manufacturing profit and the gain or loss on overheads.

VICKERS-ARMSTRONGS, LIMITED, will launch H.M.S. "Sheffield" at Walker-on-Tyne on July 23. The Duchess of Kent will perform the naming ceremony.

Making a Propeller by Snap-Flask Methods

By J. J. McCLELLAND

There are many types of castings made in specialised shops that the majority of people engaged in the foundry industry never have a chance of studying. For instance, marine engineering work is located chiefly in towns bordering on the sea coast and the inland towns rarely take interest in this type of work. It is, therefore, seldom that the inland foundryman gets an insight into the methods adopted for making such castings as ships' propellers.

Usually the large propellers are made in loam, and are shaped up with strickles and templates. This requires a special type of plant, in the shape of pitch angles, a spindle with balance weight to carry the strickle, special box parts and the like. All of these are somwhat costly, and unless a fair amount of work can be found for their use, the stock plant becomes something of a white elephant. The strickle and template can also be used for the smaller types of propellers, but it is debatable whether it is the most economical method to adopt. The sketches accompanying this article illustrate a method of making the smaller propellers by a kind of snap-flask system, and although the system requires a pattern for one blade, it should not cost more to make the pattern than it would to make the other apparatus for strickling in loam.

The author has found that for work such as is required for tug boats, trawlers and the like, this method is a very useful one. In many

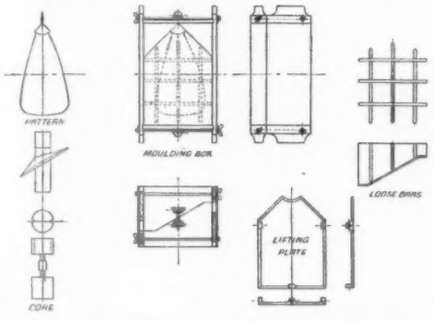


Fig. 1.—Box and other Parts for Making Propellers by Collapsible Box Method.

instances, the tug owner will agree for a propeller to be retained in stock. On the other hand, there are many instances where a propeller is required in a great hurry, and for that reason firms which specialise in this class of work must be ready to provide a new propeller in the shortest time possible. The system illustrated here has proved to be a very quick method. The mould is made and cast in green sand and propellers up to six feet in diameter can be made in this way. No time is required for drying moulds; the job can be put down in any convenient available place, and it is quite an easy matter for the experienced moulder to make a five or six feet propeller in a day. This is not possible when the mould must be put in the stove and dried.

In making a propeller by collapsible box methods, a level floor must first be made to accommodate the complete mould. The lifting plate is placed on the floor and the bottom part of the moulding box placed over it. The box is partly filled with sand, which is firmly rammed. The pattern is then fastened in position and the rest of the box rammed up to the joint which follows the shape and pitch of the blade. The top box is placed over this and the loose wood bars illustrated in Fig. 1 are wedged in their proper position. The top part is rammed up and lifted away in the usual fashion, and after the pattern has been withdrawn and the blacking applied, the mould is closed. The bolts holding the box together are released and the box can then be removed, leaving the mould resting on the lifting plate. This operation is repeated four times, or three times if it should be intended for a three-bladed casting.

When a mould is completed and the box removed, it is lifted into position by inserting

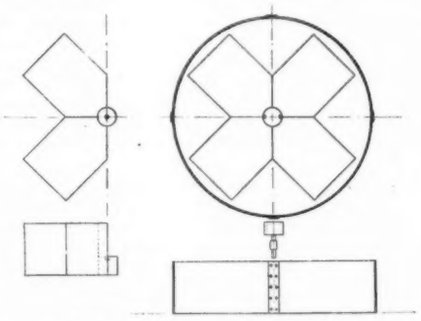


Fig. 2.—Four Moulds in Position.

three straight steel pins into the three lugs shown on the lifting plate, and to these pins a three-strand lifting rope is attached and the mould is lifted and placed in position on the level floor. It will be noticed that a long print extending the full depth of the box is attached to the blade pattern. This is done because the moulding box is intended for all sizes of propellers that will come within its dimensions.

In Fig. 2 it will be seen that when two of the moulds are placed in position, the core that forms the bottom of the boss is placed in position. Moreover, the four moulds are seen placed in position; when this has been done a kerb of boiler plates is fixed around the four moulds and the space between the kerb and the moulds is filled with sand which is securely rammed. When this is completed, a core which makes the bore in the boss and also forms the top of the boss is lowered into the space still left between the moulds and completes the shape of the entire mould. It will also be noticed that the runners are formed in the top section of the boss core.

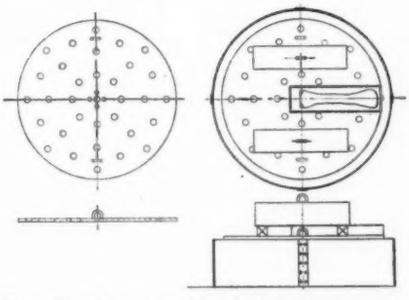


Fig. 3.—Covering Plate for Resisting Metal Pressure during Casting.

In Fig. 3 is shown what is intended for a covering plate to resist the pressure of the metal during the casting process. The plate is bedded gently on a layer of soft moulding sand and then suitable weights are placed on top of the plate, as is customary in nearly all classes of moulding and casting. The usual type of runner basin is used which is also shown in Fig. 3.

The illustrations are intended to represent a propeller 6 ft. in diameter to the end of the blades, and it will be quite obvious that the same principles can be applied to any propeller of a size less than that. The author, who has used the method for a propeller as small as 6 in. in diameter and for all sizes within these two dimensions, is of the opinion that it is the quickest and most economical method for making the smaller sizes of propellers.

Corrosion of Tin and Other Metals by Insulating Oils

Researches by P. J. Haringhuizen and D. A. Was, at Utrecht, on this subject are described in Technical Publication Series A, No. 35, of the International Tin Research and Development Council. By volatilising tin, lead or copper from tungsten filaments *in vacuo*, extremely thin films of each metal were deposited upon squares of mirror glass. By a series of measurements the thickness of the films was related to the amount of light transmitted by them. This relationship allowed the thinning of the films due to corrosion in insulating oils to be determined.

From the experiments it is concluded that the metals build up a protective film of reaction products on their surfaces. In the case of copper, this film is continuously destroyed, but tin and lead have a durable resistant film, and the diffusion through this film controls the corrosion. Experiments with different oils showed that the velocity of corrosion is not related to the concentration of the acids formed by the deterioration of the oils. The results have been expressed by an experimental formula, for which an attempt is made to provide a theoretical basis.

Copies of the publication may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C.2.

Heat Absorption in Tensile Tests

In work at the Institut für Eisenhüttenkunde of the Technische Hochschule of Aachen, H. Esser, H. Cornelius and W. Bauck have measured the heat absorbed by steel during tensile tests, using a specially designed calorimeter capable of measuring less than 1 calorie with an accuracy exceeding 90 per cent. The values obtained on elastic deformation of a plain steel were in good agreement with those published by other investigators. With plain, austenitic and ferritic steels, the heat absorption increased with the carbon content. Increase in the chromium content reduced the heat absorption to a greater degree in ferritic steels than in austenitic steels, while as the nickel content is increased, more heat is absorbed by austenitic steels than by ferritic steels. The effect of heat-treatment did not appear to follow a simple law. Heat absorption commenced above the elastic limit, attained a maximum just above the yield point, and again ceased just before constriction commences.

Making History

(*Concluded from page* 413.)

it is often exciting, never dull, and gives an entirely truthful account of his adventures. The second book is Vincent Sheehan's "In Search of History," another work mainly autobiographical in character, but autobiography is like good fiction, while much fiction is merely bad autobiography. The third book is Gunther's "Inside Europe." It is not autobiography, but the author takes each of the European countries in turn and gives a connected and rational account of the currents and cross currents in their immediate past, England included. It is serious, but amusing. All three books are lengthy, but not too long, and we think that anyone who has not come across them will find them not only illuminating but enjoyable.

Trade Conditions in the Netherlands East Indies

The Department of Overseas Trade has issued a report by Mr. L. B. S. Larkins, commercial agent in Batavia. We append a short extract which may be of interest to our readers.

Machinery, etc.—Holland and Germany were the most important suppliers of steam boilers, turbines and parts, internal combustion engines, pumps, machinery and industrial tools, electrical machinery and apparatus (other than for the motor trade), weighing and measuring machines, etc., with the United Kingdom and U.S.A. competing for the third place. As, however, many of the Netherlands exports may represent goods supplied from other countries through the intermediary of the Netherlands no precise idea of the proportion of goods of Dutch origin can be given. As the official figures for the United Kingdom's share of the import trade in internal combustion and steam engines, pumping plant, steam boilers, etc., is surprisingly small, it seems probable that some of the imports from Holland may have comprised goods of United Kingdom origin. The fact that of the 282 internal combustion and electrical motors (mostly small units) installed during the first half-year of 1935, at least 110 were of United Kingdom origin, appears to justify such a conclusion. The greatest number of the power pumping plants came from Germany. Through the vast organisations possessed by the most important importers of German machinery, German firms have held a predominating position in the market for some years and are able to offer their products at about 20 per cent. below United Kingdom quotations in spite of the difficulties resulting from the Clearing Agreement. In spite of this advantage, however, the well-known types of United Kingdom diesel and semi-diesel engines, both for industrial and marine purposes, are popular, but greater efforts should be made to market these goods. German and Netherlands distributors carry heavy stocks which they supply on credit over extended periods. Even complete factories are equipped against payment by periodical instalments. The cash transactions usually demanded by United Kingdom manufacture are, therefore, of no interest to importers. Similarly, a German group are in a favourable position to further sales of electrical machinery and apparatus, and United Kingdom manufacturers would be well advised to take steps to meet this competition. The German group, in fact, appears to hold a virtual monopoly for major works through their efficient organisation in the Netherlands East Indies.

Germany and the U.S.A. supply the majority of weighing and measuring machines. Continental and American manufacturers supply accurate and well finished articles in the metric system and although Law No. 256 of 1928 prohibits the use of weighing or measuring apparatus in any other than the metric system, there would appear to be no reason why United Kingdom manufacturers should not get a share of the trade.

The United Kingdom and U.S.A. supply the major printing machinery. Holland and Germany make small presses which before the depression sold well. Machine supplies come mostly from Holland with the United Kingdom a good second. Zinc cuts, etc., required for this trade are now all made locally.

Most of the tea machinery imported is of United Kingdom origin, but locally made rolling and drying machines have been installed in a number of factories. Such rubber machinery as is imported comes for the most part from the United Kingdom but all small sheeting machines used by native growers are made locally.

Although there was some increase in imports of United Kingdom textile machinery in 1934 and 1935, the greatest number of looms imported were of Japanese manufacture. All the machinery installed in the new equipment of the Preanger Weaving Mill at Garoet was of Japanese and German manufacture, as was also the case in the majority of the other new European and Chinese mills recently established. From both the technical and price aspects, the Japanese looms and shuttles are preferred locally to the United Kingdom articles.

Mining machinery was mostly of American and Netherlands manufacture, but the United Kingdom and Germany in the order named were also important suppliers. Most of the oilfields and refinery machinery was imported from Holland, the U.S.A. and Germany.

It should be said that in almost all cases of large contracts placed by the public utility companies, petroleum interests, etc., the material required is ordered in Holland.

The reduced demand for sugar machinery was almost entirely supplied from Holland, when that available in dismantled plants could not suit the requirements.

The United Kingdom retained the market for sewing machines and parts, with slight competition from German machines. The value of the United Kingdom imports was Fl. 540,000 in 1934 and Fl. 440,000 during the first eight months of 1935.

An order for button making machines valued at Fl. 60,000 required for a new factory at Semarang was placed with a German firm in 1935.

Refrigerators, Cooking Stoves, etc.—It may be said that perhaps with the exception of Bandoeng, where rates are more competitive, the charges for current in spite of certain reductions are still too high for electric stoves to compete effectively with gas or oil burners. Two types of refrigerator of United States make are the most popular in this market, but as ice is cheaper than electrical current many people prefer to use ice chests for domestic cold storage. Refrigerators may be obtained on the hire purchase or ordinary hire system. As the principal German and American suppliers of electric stoves, refrigerators and other domestic equipment have well organised branches in the Netherlands East Indies which carry heavy stocks, competition is rendered very difficult. The Nederlandsch-Indische Gas Mij. import a German stove which they sell on the narrowest margin of profit in order to popularise the use of cooking gas. In addition to the gratis supply of 100 cub. metres of gas with each purchase, easy payment terms are given. Japan has supplied a considerable number of oil or charcoal burning stoves.

Copies of the report may be obtained from His Majesty's Stationery Office, Adastral House, Kingsway, London, W.C.2, price 2s.

Welded Steel Bedplates Applied to Large Gear Units

With the growing tendency towards welded steel construction work in many branches of the engineering industry, nowhere, perhaps, has the fabrication of steel sections and plates been more efficiently applied than in the case of bedplates for large gear units, where the accuracy of construction and the ratio of strength to weight are effectively demonstrated.

David Brown & Sons (Hudd.), Limited, Huddersfield, have carried out considerable development and research work in this direction, necessitating the equipping of a special department with the most modern types of cutting-out machines, electric welding equipment, etc., for dealing with fabricated work up to the largest sizes.

The bedplate shown in Fig. 1 is a typical example of modern practice. It is the bed for a 91 in. centres heavy-type single reducing gear for abroad. This bed weighs only 11½ tons in comparison with the total weight of the unit, which, including bed, gears, shafts, flywheels and case, is 82 tons. It is constructed throughout from standard rolled steel sections, braced by flat plates, electrically welded, and is arranged for grouting into a concrete foundation up to the level of the top flange. The overall dimensions are 253½ in. by 115 in. by 27⅞ in. This type of bed is equipped with joggles for the accurate location of the massive, independently mounted pedestals and provides seatings for the fabricated steel casing.

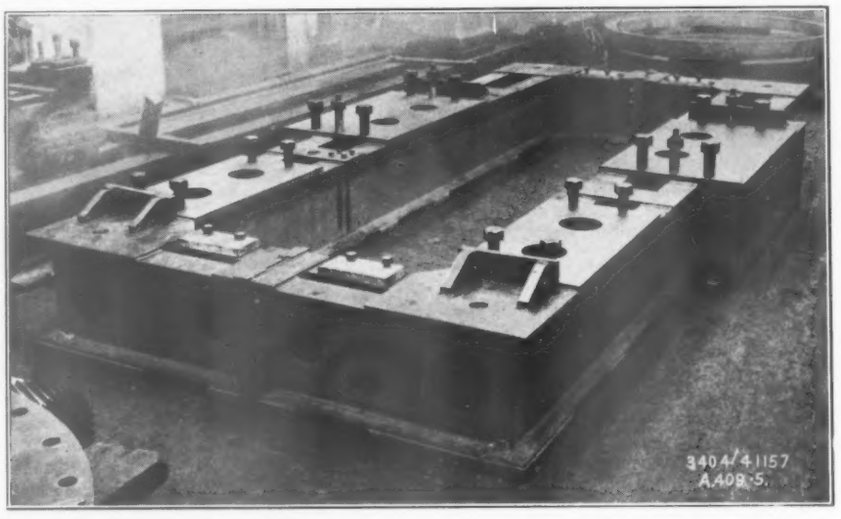


FIG. 1.—BEDPLATE OF WELDED STEEL CONSTRUCTION FOR LARGE GEAR UNIT, BY DAVID BROWN & SONS (HUDD.), LIMITED.

Welded Mild-Steel Drums

The British Standards Institution has recently issued a British Standard Specification for welded mild-steel drums, providing for three classes of drums, which are based upon a classification of liquids according to their corrosive properties and specific gravities, but gives no indication as to the particular liquids themselves. The Specification standardises the dimensions of drums in various capacities, from 5 to 150 galls., and includes details in respect of the method of construction, and the dimensions of the bung and boss. It represents an endeavour to effect the greatest practical measure of standardisation, but provision is made for a number of alternatives, so as to allow a certain amount of latitude to manufacturers and users. Copies of this new Specification, B.S.S. No. 670—1936, may be obtained from the Publications Department of the British Standards Institution, 28, Victoria Street, S.W.1. (Price 2s. 2d. post free.)

The Influence of Special Elements on the Physical Properties of Cast Iron

By J. W. DONALDSON, D.Sc.

The last ten years have shown marked progress in the development of alloy cast irons and such irons are now being widely used in all branches of the engineering industry. Special elements have been added to cast iron not only in small proportions to give improved properties, but also have been alloyed in fairly large amounts with the production of irons which have high corrosion-resisting properties and which are susceptible to heat-treatment. This alloying of cast iron with special elements in small or large proportions and using such irons either as cast or after suitable heat-treatments, has had a marked influence on the properties of cast iron. A large amount of investigation and research has been carried out on the physical properties of the alloyed cast irons, treated and untreated, particularly as regards strength, hardness, resistance to wear, corrosion resistance, surface treatment, and on properties at high temperatures. Less work, however, has been carried out on the influence of special elements on such properties as thermal and electrical conductivity, thermal expansion, and on the magnetic properties, properties which are of importance to many users of metals and properties which have got to be considered when new materials are being considered.

Thermal Conductivity

The thermal conductivity of grey cast iron has been determined by a number of investigators and consideration of their results shows that the conductivity varies from 0.100 to 0.137 cal. per cm. per sec., according to the composition and structure of the material, and that it decreases as the temperature increases. The influence of silicon within the limits 0.6 to 2.0 per cent. is to lower the conductivity, and manganese up to 1.5 per cent. has a similar effect, although to a less extent, while phosphorus up to 1.0 per cent. also tends to lower the conductivity slightly. As regards structure, free ferrite is a much better conductor of heat than eutectoid pearlite, which has been determined as approximating to 0.124 cals., owing to the relative conductivities of ferrite and cementite which have been determined at 0.174 and 0.017 cals. respectively. The influence of structure is most strikingly demonstrated by contrasting the conductivity values of a blackheart and a whiteheart malleable cast iron. The former with a structure approximating to 82.1 per cent. ferrite, 15.6 per cent. pearlite and 2.23 per cent. temper carbon has a conductivity of 0.150 at 100 deg. C., while the latter with a structure of 6.75 per cent. ferrite, 91.2 per cent. pearlite and 2.04 per cent. temper carbon has a value of 0.114 at 100 deg. C. The denseness of a cast iron also appears to affect its thermal conductivity and results have been obtained for irons of normal composition which, when cast in the form of ingot moulds, appeared to be more than normal grey iron castings, and which gave values below 0.10.

The first determinations on the thermal conductivity of alloy cast irons were made by the author[1] [2] some years ago. The alloy irons tested were two manganese irons containing 1.87 and 2.43 per cent. of manganese, two chromium irons containing 0.198 and 0.392 per cent. chromium, an iron containing 0.746 per cent. nickel, another containing 0.124 per cent. vanadium, and a third containing 0.475 per cent. tungsten. These were afterwards followed by determinations made on three nickel-chromium irons, containing 0.245, 0.30, 1.49 per cent. nickel and 0.498, 0.607, 0.54 per cent. chromium respectively; on two irons containing 4.20 and 6.49 per cent. silicon, and on a Nicrosilal iron. The thermal conductivity values for these alloy irons at 100 deg. and at 400 deg. C., together with the conductivities of plain irons of approximately the same composition are given in Table I.

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Consideration of these results shows that in general small additions of special elements tend to decrease the thermal conductivity of grey cast iron slightly, except in the case of chromium and tungsten additions which tend to raise the conductivity values, and in the high silicon and Nicrosilal irons where the values are considerably lower. Except in the case of the three latter irons, the additions of special elements are small and the structure remains unaffected, being of a pearlitic nature. It would appear, therefore, that the lowering or raising of the heat-conducting power of cast iron is influenced by the amount of the special element added to a greater extent than to changes in structure. Silicon and nickel additions lower the thermal conductivity to a greater degree than manganese or vanadium and where nickel and chromium are present together the chromium appears to counteract the influence of nickel by maintaining the conductivity at a higher value.

Where the alloy addition is larger, it has a marked influence on the thermal conductivity. This is seen in the case of the two irons containing 4.20 and 6.49 per cent. silicon. Both of these irons have a ferrite-fine graphite structure, but notwithstanding the fact that the structures are ferritic, the relative conductivities at 100 deg. C. are 0.097 and 0.088 cals., indicating that the influence of the large silicon addition is greater than that of the structure. In the Nicrosilal iron where, in addition to a high silicon content, there is also a high nickel content, and where the structure becomes austenitic, the effect is even more marked, the conductivity value falling to 0.07 cals.

The influence of composition and of structure on the thermal conductivity of unalloyed cast irons and irons containing up to 5 per cent. of silicon, nickel, chromium, or copper, has also been studied by Söhnchen[3] and the results obtained are in general agreement with those obtained by the author. The thermal conductivity of an iron is found to be lowered by alloy constituents which are in solid solution in the ground mass. Cementite lowers the conductivity to a marked extent, temper carbon has only a slight reducing effect, while an increase in the proportion of graphite carbon for a constant total carbon, increases the thermal conductivity, the extent of the modification being affected by the size of the graphite flakes, coarse graphite intensifying the influence.

Influence of Silicon and Nickel on Thermal Conductivity

Experiments carried out with silicon additions up to 5 per cent. show the thermal conductivity to decrease as the silicon content increases. With 1 per cent. silicon the thermal conductivity is 0.148 at 200 deg. C. and with 4.5 per cent. silicon 0.120 at the same temperature, while at 500 deg. C. the respective conductivities are 0.120 and 0.084 cals. This lowering of the conductivity only takes place so long as the graphite content remains constant, but when the presence of sufficient silicon causes separation of increased graphite, there is a rise in the heat conducting value. In a series of irons containing 3.5 per cent. carbon, 1 per cent. silicon, as the nickel increases to 4.3 per cent. the thermal conductivity decreases rapidly up to 1.5 per cent. nickel, then more slowly, the values obtained for the plain iron, the 1.5 per cent. nickel iron, and the 4.3 per cent. nickel iron at 200 deg. C. being approximately 0.144, 0.102, and 0.100 cals., and at 500 deg. C., 0.118, 0.082, and 0.07 cals. Replacing silicon by nickel, however, causes an increase in thermal conductivity up to a maximum at about 3 per cent. nickel.

The determinations of thermal conductivity on irons containing 3.7 per cent. carbon, 2.5 per cent. silicon with chromium addition up to 1.4 per cent. show that the influence of chromium is irregular. Generally speaking the conductivity decreases as the chromium content increases, a result which is the reverse of that obtained by the author who found a steady increase with chromium additions up to 0.5 per cent. chromium. Söhnchen also determined the influence of copper on the thermal conductivity of cast iron containing 3 per cent. carbon, 2.3 per cent. silicon and found that with copper up to 1.5 per cent. the conductivity was lowered. With additions of copper, however, in excess of this amount the influence was in the reverse direction and the conductivity increased.

From the investigations which have been carried out, it is seen that the general influence of special elements on the thermal conductivity of grey cast iron is to produce a decrease.

TABLE I.—*Thermal Conductivities of Alloy Cast Irons (Donaldson).*

Composition, per cent.							K	
C	Si	Mn	Ni	Cr	V	W	100 deg. C.	400 deg. C.
3.16	1.48	0.97	—	—	—	—	0.122	0.107
3.25	1.56	1.87	—	—	—	—	0.120	0.104
3.32	1.52	2.43	—	—	—	—	0.118	0.101
3.19	1.42	0.96	—	0.198	—	—	0.127	0.112
3.17	1.40	0.97	—	0.392	—	—	0.131	0.114
3.16	1.56	0.94	0.746	—	—	—	0.108	0.101
3.19	1.54	0.99	—	—	0.124	—	0.122	0.103
3.25	1.91	0.81	—	—	—	—	0.110	0.103
3.02	1.89	0.76	—	—	—	0.475	0.118	0.105
3.30	1.89	0.71	0.245	0.498	0.013	—	0.108	0.102
3.33	1.21	0.64	0.300	0.607	0.020	—	0.118	0.103
3.41	1.03	—	1.49	0.54	—	—	0.116	0.104
3.02	4.20	—	—	—	—	—	0.097	0.092
2.75	6.49	—	—	—	—	—	0.088	0.082
1.81	6.42	—	18.65	2.02	—	—	0.070	0.064

Chromium, tungsten and copper additions give somewhat irregular results, and their influence is not definitely established. Where the amount of special element added is small, and where the structure is not materially affected, the decrease in heat conducting power is small, but where the additions are large, as in the case of irons containing 4 to 6 per cent. silicon, or where the structure is affected by large additions of special elements, as in the case of Nicrosilal, where an austenitic structure is produced, the decrease in thermal conductivity is most marked. Results of a somewhat similar nature have been obtained by Shelton[4] on alloy steels and by Hattori[5] on high speed tool steels. The former

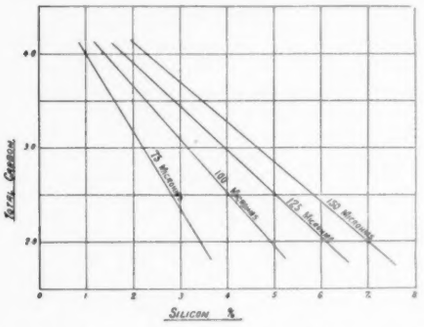


Fig. 1. Electrical Resistivities (Microhms per cm. cube) of Grey Cast Irons containing 2 to 4 per cent. T.C., and 1 to 8 per cent. Si_2 (Norbury and Morgan).

found a slight falling off in the thermal conductivity of steels containing small additions of nickel, chromium or tungsten, and a very decided decrease in steels with large additions of added elements, such as the 13 per cent. chromium steels and the 18-8 steels. Hattori's values for the high speed steels also show a large decrease in thermal conductivity.

Differences between Cast Iron and Steel

In comparing the influence of special element additions on the thermal conductivities of cast iron and steel, there are certain differences to be noted. Large additions of special elements to steel, as in the stainless and 18-8 steel, cause a greater falling off in conductivity than do similar additions to cast iron. The average value for 13 per cent. chromium steel at 100 deg. C. is 0.060, and for 18-8 steel at the same temperature 0.040, whereas Nicrosilal cast iron containing 18.5 per cent. nickel, 2.0 per cent. chromium and 6.5 per cent. silicon, has a value of 0.070 at 100 deg. C. Again, all alloy cast irons show a decrease in conductivity for a particular iron as the temperature rises in contrast to steel, where high alloy steels, stainless, 18-8 and high speed steels show an increase in conductivity for a particular steel as the temperature rises. The thermal conductivity of 13 per cent. chromium steel at 100 deg. and 400 deg. C. is 0.060 and 0.064 respectively, and of Nicrosilal cast iron 0.070 and 0.064 at the same temperatures. The decrease of conductivity in the latter iron with increase in temperature is not so marked, however, as that which occurs in ordinary cast irons, as is shown in Table I. The reason why cast iron with high alloy additions should behave differently from high alloy steel with variation in temperature is not easy to explain, but may be due to the presence in the latter of the graphite flakes.

Electrical Conductivity

The electrical conductivity of cast iron in terms of its specific resistance or electrical resistivity has been determined by Masumoto, Partridge, Pinsl, Norbury and Morgan, and Söhnchen. Investigations have been principally confined to determining the influence of silicon and carbon upon this property, but the influence of special element additions have been investigated by Partridge[6] and Söhnchen,[3] the former determining the influence of silicon, aluminium, manganese, cobalt and nickel, and the latter the influence of silicon nickel, silicon and nickel, chromium, and copper.

The various investigations on the electrical resistivity of normal grey cast iron with carbon up to 3.5 per cent. and silicon up to 1.5 per cent. have shown that such irons have thermal resistivity values varying from 25 to 75 microhms per c.c. at ordinary temperatures. Increase in combined carbon and increase in temper carbon increases the electrical resistivity, and a similar result is produced by increasing the proportion of graphite for a constant total carbon content. Refining the graphite and the grain size diminishes the resistivity. Increasing the silicon content above 1.5 per cent. produces an increase in the electrical resistivity. Determinations by Norbury and Morgan[7] on a series of irons containing from 2 to 4 per cent. carbon and 1 to 8 per cent. silicon, show that an increase in the silicon or total carbon content has an increasingly greater effect, the higher the silicon or total carbon content.

Consideration of Fig. 1 shows that in an iron containing 2.5 per cent. carbon, increasing the silicon from 3 to 6 per cent. increases the resistivity by about 75 microhms per c.c., and in an iron containing 4 per cent. carbon, increasing the silicon from 1 to 2 per cent. increases the resistivity by 50 michrohms per c.c. Some of the irons had a fine graphite structure and others a coarse graphite structure, but the results were not sufficiently systematic to show the influence on resistivity of differences in graphite structure as distinct from graphite content. The same workers[8] also determined the electrical resistivities of a series of irons containing up to about 6 per cent. aluminium, between 6 to 19 per cent. manganese, and up to 5 per cent. silicon, and found the resistivities to vary between 112 and 253 microhms per c.c., according to the composition. The resistivity increases as the silicon content increases and as the graphite content increases, while aluminium has a similar influence, although to a smaller extent. The direct influence of manganese is to raise the resistivity, but its indirect influence is to lower it by replacing graphite with carbide.

The results of Partridge, Pinsl and of Söhnchen are shown in Fig. 2. Partridge found that,

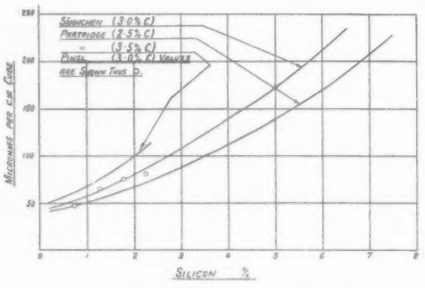


Fig. 2.—Influence of Silicon on the Electrical Resistivity of Cast Iron containing varying Carbon Contents.

with an iron containing approximately 2.5 per cent. carbon, increase in silicon from 2.54 to 7.38 per cent. increased the electrical resistivity from 86.2 to 217.7 microhms per c.c. Annealing at 875 deg. C. decreased the values slightly to 75.3 to 213.5 microhms per c.c. Söhnchen experiments carried out on irons containing 3 per cent. showed the electrical resistivity to increase from 50 to 235 microhms per c.c. with an increase in the silicon content from 1.0 to 5.8 per cent.

The influence of nickel on the electrical resistivity of cast iron is shown in Fig. 3, which summarises the results of work by Partridge and by Söhnchen. The former's determinations were carried out on a series of nickel irons containing 3.5 per cent. carbon and 0.1 to 0.3 per cent. silicon, and show the resistivity to increase at first rapidly and then more slowly with increase nickel content to a value of 134 microhms per c.c. with 18.8 per cent. nickel, while the latter with an iron containing 3 per cent. carbon, 0.8 per cent. silicon and nickel additions up to 4.5 per cent., obtained a curve of a somewhat similar nature. Söhnchen also found that if the silicon constituent is replaced by nickel the resistivity is decreased, and determined the ratio of silicon to nickel and its influ-

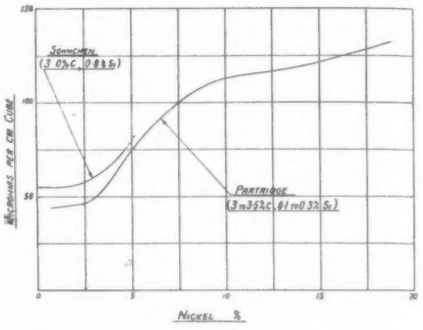


Fig. 3.—Influence of Nickel upon the Electrical Resistivity of Cast Iron.

ence on the resistivity, and found the decrease to be at a minimum with 3 per cent. nickel.

The influence of alloy additions of manganese, aluminium, cobalt and chromium on the electrical resistivity of cast iron, as investigated by Partridge, is shown in Table II. Increase of manganese from 0.23 to 2.66 increases the resistance from 61.9 to 66.5 microhms per c.c. in the as cast condition, and annealing produces little change. Aluminium additions from 0.87 to 4.09 per cent. produce a rise in the resistivity which is greater than that produced by similar additions of nickel, but like manganese is less than those produced by similar amounts of silicon. Increasing the cobalt from 1.86 to 23.3 per cent. produced a decrease in electrical resistance of over 50 per cent. from 82.6 to 34 microhms per c.c., while chromium up to 1.79 per cent. increased the resistivity, a further addition up to 7.51 per cent. produced a large decrease.

The irregular influence of chromium has also been found by Söhnchen, whose results are given in Table III, and which show the influence of chromium additions up to 1.5 per cent. to an iron containing 3.7 per cent. carbon and 2.5 per cent. silicon. The general effect of these small additions of chromium is to lower the electrical resistivity. The values obtained are somewhat similar to those obtained for the two low chromium irons tested by Partridge. Söhnchen also found that on adding copper to an iron containing 3 per cent. carbon, 2.3 per cent. silicon, an addition of 0.55 per cent. gave an electrical resistivity of 74 microhms per c.c. With 0.90 per cent. copper, the resistivity increased to 80 microhms but decreased to 74 microhms with a further addition of copper to 1.9 per cent.

In general the addition of silicon, manganese, nickel, or aluminium to grey cast iron is to produce a rise in its electrical resistivity. Additions of cobalt cause the resistivity to decrease, while with copper the resistivity increases slightly to a maximum with 1 per cent. copper and then decreases. Chromium gives irregular results, but its general influence is to decrease the electrical resistivity of cast iron.

Thermal Expansion

Values have been determined for the thermal expansion of cast iron over a range of temperature, and are fairly accurate within limits, but

show variation with the composition and structure of the irons. Such values show the co-efficient of thermal expansion of grey cast iron to vary from 0.9 to 1.5 × 10^{-5} over the range 0 deg. to 1,000 deg. C.

With regard to the influence of alloy additions, very few systematic investigations have been carried out. Norbury and Morgan's investigations on irons of the Silal (4 to 8 per cent. silicon) and Nicrosilal type have shown that where the matrix is of a ferrite-fine graphite nature, the average co-efficient of expansion is about 1.4 × 10^{-5} per 1 deg. C., but where the matrix is austenitic in character the average value of 1.8 × 10^{-5} is obtained. Wood[9] has obtained data on the thermal expansion properties of cast irons containing 0 to 70 per cent. nickel covering the ferritic, martensitic, and austenitic types of irons. The non-magnetic austenitic cast irons containing 18 to 22 per cent. nickel have a high co-efficient of thermal expansion, whereas those with 27 to 45 have low expansion characteristics, a minimum value being obtained with 34 to 35 per cent. nickel. The substitution of nickel and copper in the Monel ratio for an equivalent amount of nickel produces expansion properties comparable with those shown by irons containing 15 to 20 per cent. nickel, but at higher ranges the nickel-copper cast irons have higher expansions than those obtained in the corresponding copper-free cast irons. Wood emphasises the fact that the data given do not present a systematic study of the influence of varying nickel contents on the expansion characteristics of a uniform cast-iron base mixture, but rather comprises an assembly of information on various alloy irons whose compositions have been specially adjusted to produce in addition to their characteristic expansion other useful engineering properties.

TABLE II.—*Electrical Resistivities of Alloy Cast Irons (Partridge).*

Composition, per cent.						Resistivity microhm per c.c.	
C	Si	Mn	Al	Cr	Co	As cast.	Annealed at 875 deg. C.
2.64	1.72	0.23	—	—	—	61.94	59.04
2.82	1.74	0.63	—	—	—	59.36	59.50
2.69	1.73	1.07	—	—	—	59.40	62.10
2.73	1.70	1.49	—	—	—	64.95	66.15
2.65	1.47	2.66	—	—	—	66.50	—
3.61	0.03	Trace	0.87	—	—	50.30	—
3.63	0.03	,,	1.52	—	—	74.60	—
3.52	0.02	,,	2.23	—	—	79.00	—
3.64	0.023	,,	2.50	—	—	86.25	—
3.50	0.025	,,	2.83	—	—	87.10	—
3.61	0.018	,,	3.60	—	—	89.30	—
3.42	0.02	,,	4.09	—	—	94.70	—
2.59	2.63	0.02	—	0.63	—	90.63	—
2.42	3.63	Trace	—	1.06	—	—	—
2.45	3.12	0.015	—	1.79	—	113.5	—
2.10	1.71	0.01	—	7.51	—	64.6	—
2.76	2.18	0.045	—	—	1.86	82.60	—
2.91	0.905	0.02	—	—	6.51	68.80	—
2.36	0.66	0.01	—	—	19.9	38.90	—
2.20	0.65	0.01	—	—	23.3	34.40	—

TABLE III.—*Electrical Resistivity of Chromium Cast Iron (Söhnchen).*

Composition. per cent.			Resistivity microhms per c.c.
C	Si	Cr	As cast.
Approximately 3.7 per cent.	Approximately 2.5 per cent.	0	110.0
		0.25	100.0
		0.5	87.0
		0.75	83.0
		1.0	100.0
		1.25	80.0
		1.5	91.0

A systematic study of the influence of special element additions on the co-efficient of thermal expansion of cast iron has been made by Söhnchen and Bornhofen,[10] who determined the influence of carbon, silicon, phosphorus, nickel, copper, aluminium and chromium on this property. So far as carbon, silicon, and phosphorus influenced the thermal expansion of cast iron, these investigators found the co-efficient of expansion to decrease linearly with increase in carbon content, but where carbide decomposition occurred there was an increased value of the co-efficient. Silicon produced a slight increase up to 1.5 per cent., after which the expansion decreased, while phosphorus up to 1.5 per cent. did not affect the expansion.

Determinations made on cast iron containing 3 per cent. carbon with medium additions of nickel up to 6 per cent. showed the co-efficient of thermal expansion to increase slightly with 1 per cent. of nickel and then to decrease slightly. In an iron of similar carbon content, copper additions produced a linear increase in the expansion varying according to the temperature from 0.85 to 1.20 × 10^{-5} with 0.5 per cent. copper to 0.95 to 1.3 × 10^{-5} with 2.0 per cent. copper. Additions of aluminium up to 8 per cent. in an iron containing 3.5 to 3.8 per cent. carbon also caused a linear increase in the expansion. The values obtained with 2 and 8 per cent. aluminium being 0.7 × 10^{-5} and 0.9 × 10^{-5} respectively over the range 20 to 100 deg. C., and 1.25 × 10^{-5} and 1.3 × 10^{-5} over the range 20 to 500 deg. C. Addition of chromium increases the co-efficient of thermal expansion rapidly from 0.62 × 10^{-5} in an iron containing 3.5 to 3.8 per cent. carbon to 10.4 × 10^{-5} with 0.5 per cent. chromium, but with more chromium the co-efficient decreases rapidly to 0.85 × 10^{-5} with 1.0 per cent. chromium, and then more slowly to 1.5 per cent. chromium when the value is 0.83 × 10^{-5}, over a temperature range 20 to 100 deg. C. At higher temperature ranges the expansion is greater, but the general influence of chromium is similar.

Magnetic Properties

Little work was done on the magnetic properties of cast iron until the systematic investigations of Partridge[6] were undertaken some ten years ago. This investigator, in determining the influence of various metals on cast iron, found that the form in which carbon is present greatly influences the magnetic properties. Graphite does not affect the hysteresis loss, but prevents the attainment of a very high magnetic induction, especially if present in flakes resulting from a lack of magnetic continuity, nodular graphite gives a higher induction. Ferrite gives low hysteresis loss and high permeability, while pearlite gives high hysteresis loss and low permeability. Silicon, therefore, decreases the magnetic induction of cast iron in the cast state and reduces both the coercive force and hysteresis loss of both cast and annealed cast iron. Manganese up to 2.66 per cent. both in the cast and annealed conditions lowers the magnetic induction, and in the annealed condition increases the coercive force and hysteresis loss and decreases the remanent magnetism. Phosphorus has little effect on the magnetic properties of cast iron.

Partridge also determined the influence of alloy additions of aluminium 0.31 to 4.09 per cent.; chromium 0.63 to 7.51 per cent., cobalt 1.86 to 23.3 per cent., and nickel 0.71 to 18.83 per cent. Aluminium decreases the magnetic induction, permeability, remanent magnetism, and increased the coercive force, and hysteresis loss of iron in the cast condition. In the annealed condition, however, aluminium up to 3 per cent. increased the induction and permeability to a large extent, and decreased to a considerable extent the coercive force and hysteresis loss. In the cast condition, chromium gives a high coercive force, but reduces the remanent magnetism to a very small amount, while in the annealed condition the same element decreases the coercive force and hysteresis loss and the remanent magnetism. Cobalt increases the magnetic induction, remanent magnetism, and permeability of cast iron, but has little effect on the coercive force and hysteresis loss, which remains high. Annealing increases the permeability, and decreases the coercive force, hysteresis loss, and remanent magnetism. Nickel decreases the permeability to such an extent that cast irons containing over 15 per cent. nickel are non-magnetic, due to the formation of an austenitic structure.

The magnetic permeability of aluminium-manganese-silicon cast irons was investigated by Norbury and Morgan,[5] who found that for an iron containing 2 per cent. aluminium, 2 per cent. silicon, and 8 per cent. manganese the magnetic permeability was 1.11. This iron was fairly soft and machinable. With less than 7 per cent. manganese the permeability increases due to the presence of martensite, but with the addition of 1 to 2 per cent. nickel, the permeability is lowered still further. In other compositions containing more than 7 per cent. manganese and 2 per cent. aluminium, the permeability is never more than 1.7, and rises to this value as the amount of carbide present increases, the carbide being magnetic.

The magnetic properties of cast iron, permeability coercive force, remanent magnetism, and saturation, have also been studied by Söhnchen, both as a function of the form in which the carbon is present and also with regard to the content of silicon, phosphorus, manganese, nickel, aluminium, copper, and chromium. His investigations show that with a high silicon content (6 per cent.) and a low carbide content magnetically soft cast iron is produced, but with a low silicon content (2 to 2.5 per cent.), together with an addition of chromium or copper and a very fine distribution of the graphite, magnetically hard cast iron is produced. Phosphorus up to 1.6 per cent. has practically no effect on the magnetic properties of cast iron.

Two series of nickel cast irons were examined: in the first the silicon was kept constant at 0.8 per cent. and the nickel varied from 1.6 to 4.43 per cent., while in the second series the silicon was replaced by nickel in varying ratio (nickel/silicon:—0.90/1.76; 1.85/1.26; 2.70/0.70; 3.95/0.14; 5.63/0.30, and 3.70/0.72). In the first series a marked rise in coercive force was obtained with over 2 per cent. nickel, and a corresponding fall in permeability. Saturation at first rises slightly as a result of increased graphite content, but with over 3 per cent. nickel formation of austenite causes a marked decrease. In the second series of irons, the increase in nickel at the expense of silicon produces a sharp rise in the coercive force, while remanent

(*Concluded on page 423.*)

Technology of Cast Light Alloys and Their Application in Motor-Car Construction*

By A. DUMAS.

By decreasing the weight of a motor-car one increases its acceleration, improves its hill climbing qualities, reduces petrol and oil consumption and tyre wear. In addition to decreasing the weight a number of other important advantages result from the use of aluminium in motor car construction. Aluminium has a thermal conductivity which is three to four times that of cast iron and is superior to that of a number of copper alloys. Hence a direct advantage attaches to the use of aluminium for pistons, cylinder heads, cylinder blocks, oil sumps, brakedrums, etc.

In the case of cylinder heads the use of aluminium further results in a more even temperature owing to the high thermal diffusibility of aluminium, which is five to six times that of cast iron. The formation of " hot spots " is thus avoided. Aluminium and its alloys present the great advantage in being readily machinable, enabling a high cutting speed to be used. Aluminium alloys can be readily used for sand, chill and pressure die casting. The chill-casting technique of aluminium alloys has been considerably developed and presents obvious advantages for the casting of aluminium alloy parts, ensuring as it does accurate castings being obtained which necessitate a minimum of machining.

Pressure die casting may be used for the mass production of small parts. Aluminium-copper alloys containing 8 to 10 per cent. copper have been used for casting motor-car parts. Additions of silicon may be made to improve their casting properties. An alloy containing 14 per cent. of zinc and 2 to 3 per cent. copper is being used by certain manufacturers. The alloy containing 13 per cent. Si has excellent casting properties. A fine grain may be obtained by suitably " modifying " the alloy which then has a tensile strength of 12.5 tons per sq. in. and an elongation of 6 to 7 per cent. Its fatigue limit may be increased by an addition of about 0.8 per cent. copper and in some cases 0.5 per cent. manganese. The addition of manganese to an aluminium-silicon alloy renders the alloy amenable to heat-treatment which results in a further considerable increase in its mechanical properties.

Alloys of the " Magnalium " type containing 7 to 12 per cent. of magnesium can be satisfactorily cast provided certain precautions are taken in melting and casting the alloy. Alloys containing more than 7 per cent. magnesium can be heat-treated. In addition to the above types of alloys a number of special alloys are known which have been developed to meet specific requirements. The use of an aluminium alloy for pistons was at first intended merely to reduce the weight of the pistons. It is now generally recognised, however, that the most important feature is the ability of the cylinder to dispose rapidly of the heat which is developed. The design has accordingly been suitably modified.

Further researches have been carried out to try and reduce the variations in the distance between piston and cylinder wall at different temperatures and to reduce the " running-in " period. For the use in pistons the tendency has been to replace the copper-aluminium alloys by modified high-silicon content alloys which have a much smaller coefficient of expansion (about 20×10^{-6}), and at the same time are sufficiently hard. In some cases a suitable heat-treatment is necessary to avoid the phenomenon of permanent expansion. A relatively recent development is the anodic oxidation of pistons, which improves their wearing and oil retaining properties.

The main advantage attaching to the use of aluminium for cylinder heads is that its high thermal conductivity enables the raising of the compression ratio. This may be further increased if a suitable design of explosion chamber is used. The alloys at present used for cylinder heads are either the 13 per cent. silicon alloy, with addition of copper and manganese, or an 8 per cent. copper alloy containing 2 per cent. silicon or nickel. Y-alloy has been found particularly suitable for air-cooled engine cylinder heads owing to its considerable heat resistance. Cylinder heads are generally cast in sand moulds of which one side is made up of a metal die which enables a more accurate casting being obtained.

Aluminium cylinder blocks require a certain amount of strengthening, in view of the lower rigidity of aluminium as compared with cast iron. This can be readily done by introducing strengthening ribs. From the point of view of satisfactory castings, one should avoid excessive thickness, sudden changes in cross section and acute angles. Aluminium cylinder blocks necessitate the use of steel cylinder linings. An Alpax type of alloy appears to be the most suitable for cylinder blocks. Chill casting is used whenever possible. The use of aluminium alloys has been extended to such parts as the gear box, steering-gear casting, oil and water pumps and the oil sumps. In the case of the latter, the use of a finned aluminium sump reduces the oil temperature by 10 to 15 per cent.

The road holding and steering qualities of a car are improved by reducing the total unsuspended weight, *i.e.*, wheel and brake work. Aluminium alloy brakedrums are provided with cast-in cast-iron linings. Overheating of the brakes is reduced owing to the excellent heat conductivity of aluminium and by the use of cooling fins. In addition to their light weight, aluminium alloy wheels have the advantage of being non-tarnishing. The same non-tarnishing properties make aluminium an ideal material for all interior fittings, which, if required, may be anodised and coloured to suit any colour scheme.

* A Paper read before a meeting of the Société des Ingenieurs de l'Automobile and extracted by " Light Metals Review."

Useful Hints on Income Tax

By F. J. TEBBUTT.

A few hints on income tax procedure may be useful at this period, as, although much is doubtless known, so much may be forgotten just when required by both the newer and the older men of business. Business profits are assessable; profits, if classified as capital or casual, are not assessable, these being of a non-recurring or isolated nature (*e.g.*, profits on sale of a house, of premises, of goodwill, of a business, of investments), and premiums on leases and Stock Exchange transactions are usually ignored. Business expenses are deductible; private expenses, such as drawings, maintenance and dwelling house expenses are not deductible, although, if a dwelling house is used partly for business, a proportionate amount for rent or annual value, rates, lighting and heating expenses can be deducted.

Letting furnished rooms is assessable; letting unfurnished rooms not assessable, but if rooms are let off in business premises, the rent received need not be returned, but the full rent or annual value of the premises cannot be deducted; consideration must be given to parts sub-let. Advertisement expenses are allowed; but a big outlay to start a business, expenditure on own hoardings, electric signs and so forth may be considered as capital and disallowed. Welfare schemes, hospital donations, etc., if for employees' benefit, are deductible; otherwise, charitable donations are not allowed. Trade association expenses are usually allowed—there is a special arrangement between certain bodies and the Revenue department—broadly, allowance as a charge is determined by whether the association is one for the advancement of the industry in question. Business legal expenses are allowed; otherwise not allowed. Lump sums for patents, damages and legacies are not assessable; annual annuities, etc., are assessable. Travelling expenses on business allowed; but payments are not allowed for transit to and from business. Broadly, all expenditure to earn profits, whether made voluntarily or of necessity, is allowable; but expenses to provide for future contingencies are usually disallowed.

A loss incurred outside business is not deductible; but a loss in one business can be set against profits in another business under the same ownership (*e.g.*, private ownership or partnerships); holding shares in a company does not constitute ownership for this purpose. A loss can be set against a subsequent year's profit, but the amount must be taken within six years, although if the taking of wear and tear has prevented this being used in that period, a carry forward to that extent can be made beyond the six years.

Depreciation and Obsolescence

Depreciation amounts in ordinary accounts are not allowable, but a yearly percentage allowance for wear and tear of machinery and plant (this term includes all motor vehicles—22 per cent.—and fittings and fixtures) is given on written-down values each year; wear and tear allowances can be carried forward indefinitely. Under the obsolescence rule, the cost of new machinery and plant for replacements of old is allowed, after any wear and tear allowances given have been deducted. Obsolescence amounts operate as a trading expense before income is returned; wear and tear allowances must be claimed on the form after income is returned. Expenses under Schedule D (business profits) are, of course, deducted before income is returned; under Schedule E (employments-directorships) a claim must be made on relevant space on the form. Income in the year ending April 5,

(*Concluded in previous column.*)

(*Concluded from next column.*)

1936, is to be returned under both Schedules D and E, but for Schedule D, if a firm's accounting year ends earlier, that date can be substituted. Bad debts are deductible; doubtful debts may be allowed at something less than 20s. in the pound. Tax legally payable remains payable, though subsequently profits may be lost otherwise, spent or given away.

"Wear and Tear" Percentages

Here are a few " wear and tear " agreed percentages of trade interest.

Brass Foundries.—Electric motors, dynamos, and other electrical plant, 7½ per cent. Other plant and machinery, 7 per cent.

Emery, grinding, glazing and other wheels, utensils, belting, electric cables, or furnaces, not dealt with under " wear and tear," but costs of replacements and repairs are allowed as expense under " renewals."

Electric furnaces and plant and machinery used in connection therewith. All parts of furnace (including transformers, switch gear, high and low cable connections, furnaces, tilting gear and regulators), 12½ per cent.—this does not apply to foundations, buildings, cranes, or any shop tools or equipment.

Pig-iron and Steel Manufacture.—Plant and machinery generally (excluding furnaces, but including plant and machinery ancillary to furnaces), 7½ per cent. (The foregoing applies to steel, rolling, forging, hammering and re-rolling.)

Motor vehicles, 20 per cent., plus one-tenth, giving 22 per cent.

The Heat Treatment of Cast Iron*

By A. A. TIMMINS, A.I.C.

Introduction

Although heat treatment has been applied successfully to steel during the past twenty years, the heat treating of cast iron is of more recent origin. The relative brittleness of cast iron is often a handicap to its use, and whilst malleable cast iron is sometimes specified there is a growing need for an intermediate material—a need well satisfied by heat treated cast iron. This type of cast iron combines all the advantages of cheapness and wear resistance with greater toughness and moreover gives higher strength-weight ratios. For these reasons heat treated irons are finding useful application in the automobile industry to withstand the severe working conditions of modern engines. A knowledge of the physico-chemical changes occurring in cast iron is essential to a study of the heat treatment of this material.

The presence of pearlite as a constituent in the structure of cast iron is now a well-recognised fact. The formation of this constituent, consisting of alternate lamellæ of iron and iron carbide, from the solid solution austenite is accompanied by a definite arrest as shown in any cooling

FIG. 1.—STRUCTURE OF GREY CASTING BEFORE ANNEALING.
ETCHED IN PICRIC ACID.
× 200 DIAS.

curve taken of cast iron. This is the pearlitic transformation point occurring at 720 to 780 deg. C. A normal steel or cast iron possessing 0.85 to 0.9 per cent. combined carbon will in general show a wholly pearlitic structure. Pearlite is not so stable in cast iron as in steel, and in some cases, such as in large thick-sectioned castings where slow cooling is possible, or where some graphitising agent is present, the combined carbon will be less than 0.9 per cent., and the structure will show the soft constituent ferrite as well as pearlite. In other cases, such as in thin, rapidly cooled samples, or where a carbide-stabilising element is present, combined carbons higher than 0.9 per cent. will result. The structure of the iron would then show no ferrite, but pearlite and cementite in massive form giving a hard cast iron.

The heat treating of cast iron is, in some respects, similar to that of steel, but the presence of silicon, which causes instability of pearlite, will introduce modifications. The annealing of medium silicon cast irons below the critical change point produces very little breakdown of pearlite. Consequently, little change in hardness is to be expected. In order to soften cast iron and decompose the carbide successfully, it is necessary to anneal nearer the transformation range. Increased silicon will render the iron more susceptible to annealing despite the fact that the critical point is raised. When hardening cast iron it must be heated above the transformation point before quenching. Commercial cast irons contain silicon, plus manganese, sulphur, phosphorus, and sometimes nickel and chromium. Their influence may be briefly summarised.

Silicon.—Silicon in normal engineering cast iron may range from below 1 per cent. up to 3 per cent. It is a graphitising element reducing the amount of combined carbon. Silicon also lowers the amount of carbon required for the eutectoid and raises the temperature of the pearlite transformation.

Sulphur and manganese, when in proportions sufficient to form manganese sulphide, are of small importance and may be disregarded.

Nickel.—This element is present up to 1 per cent., and has a mild graphitising action (one-third that of silicon). It lowers the critical point and decreases the critical quenching speed.

Chromium.—Chromium is a carbide stabiliser equal and opposite to silicon, tending to inhibit graphitising. It raises the critical point and decreases the critical quenching speed.

Molybdenum.—This element is a carbide stabiliser lowering the critical point and decreasing the critical quenching speed.

The lowering of the critical point, carbide stabilisation and the decreasing of the critical quenching speed are factors frequently used to advantage, resulting in easier manipulation and less drastic quenching treatment. Heat treatment is employed for cast iron with the following objects in view:—(1) The relief of casting stresses; (2) the production of easily machinable cast iron; (3) the production of hard cast irons by quenching, etc., and (4) heat treatment for special purposes.

Relief of Casting Stresses

Many castings, particularly those of uneven section, have internal stresses set up during the solidification of the metal. Such stresses, if not relieved, frequently cause warping, and may eventually lead to cracks. The old method of avoiding such occurrences was known as ageing, a process consisting of storing the castings for a time, varying from a few days to months. During this time the stresses between the different sections slowly relieve themselves mainly through daily temperature changes due to weather conditions. Modern mass production methods condemn this on account of the vast amount of time involved. In modern practice the castings are placed on suitable racks and allowed to travel through a muffle, the temperature gradually rising to about 400 to 450 deg. C. After soaking at this temperature for some hours, depending on the section, the castings are allowed to cool slowly. It is important to have slow, even cooling, or otherwise new stresses will be set up and the castings will be distorted. By treating the castings at this temperature well below the critical point the metal is rendered sufficiently plastic to allow the release of stresses without causing decomposition of the pearlite. In modern pearlitic castings very little loss in hardness or tensile strength is encountered. Indeed, in very intricate castings release of stress may actually cause an increase in the strength of the casting. In very open-grained irons where the pearlite is comparatively coarse it is desirable to anneal at about 350 deg. C.

Annealing to Soften Cast Iron

In production work where reduction in machining costs is required, it is necessary to soften cast iron in order to achieve the increased cutting speed. In dense pearlitic irons very little decrease in hardness is noticeable by annealing at temperatures below the critical point. At this temperature and above, the carbide of the pearlite readily decomposes into ferrite and carbon, the latter being deposited to a certain extent on the existing graphite flakes. The usual temperature of annealing is about 790 deg. C., and the operation consists of heating at this temperature in a furnace of the counterflow type for sufficient time to allow of heat penetration. The castings are then allowed to cool slowly to minimise re-solution of graphite and formation of internal strains. In the case of certain alloy cast irons containing small amounts of carbide stabilising elements it may prove necessary to increase both time and temperature of the anneal to accomplish the desired result. It is often desired to machine or drill holes in light castings where the presence of fins or damp sand has caused the iron to solidify white. Here the hard unmachinable spot is due to the presence of massive free iron carbide as well as of pearlite.

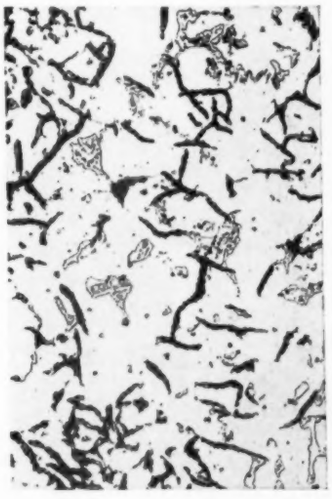


FIG. 2.—STRUCTURE OF CASTING SHOWN IN FIG. 1 AFTER ANNEALING.
ETCHED IN PICRIC ACID.
× 200 DIAS.

Such irons generally require a longer time or a higher temperature of anneal than ordinary irons in order to decompose the bulky cementite crystals. A temperature of 850 to 870 deg. C. is suitable in such cases. These black or dead annealed irons are very soft, having a Brinell hardness of 120 to 140, depending on their silicon content. Fig. 1 shows the structure of a grey iron before annealing, and Fig. 2 that after annealing. Fig. 3 shows the structure of a hard spot typical of thin casting, whilst Fig. 4 shows the same spot after annealing to break down the carbide.

Heat Treatment by Quenching and Tempering

This type of heat treament may be divided into three operations, viz.: (*a*) Heating for quenching; (*b*) quenching, and (*c*) tempering or drawing.

The samples are placed in the furnace, slowly heated to about 20 deg. C. above the critical point, and then held there until heat penetration is complete. Usually half an hour per ½-in.

* Reproduced from the Proceedings of the Staffordshire Iron and Steel Institute, Vol. 50, 1934-35, with the addition of illustrative photomicrographs, kindly supplied by the Cast Iron Research Association. The author was awarded the Institute's Bronze Medal and Prize.

section is allowed for this soaking. Samples containing free cementite usually require a longer time to ensure complete solution of the carbides. When the desired soaking has been attained the casting is removed and quickly quenched in some medium such as oil, sulphuric acid, or water, depending on the hardness required. Water quenching is often too drastic for cast iron, particularly if the articles are of intricate design, whilst air cooling, except in certain air hardening irons, results in a softening action. Care

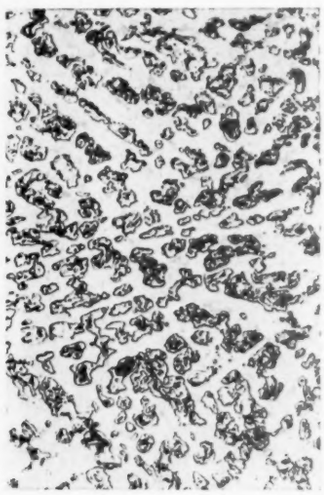


Fig. 3.—Structure of Hard Area in a Casting before Annealing.

Etched in Picric Acid.
× 200 dias.

should be taken to achieve accurate quenching temperatures and also to avoid oversoaking. In steel treatment the higher the quenching temperature the greater the resulting hardness, and this is true to a certain extent for cast iron. This effect, however, is offset by the tendency of alloy irons to form austenite, a relatively soft constituent. Therefore it is to be expected that the hardness will decrease as the quenching temperature is raised above a certain optimum. Hurst* in his experiments found the best hardening temperature to be 875 deg. C. and inferior hardness resulted by quenching from 920 deg. C. Additions of carbide stabilisers such as chromium and molybdenum inhibit graphitisation and so permit higher hardness values. Such elements are useful in that they decrease the critical quenching speed. This means that for a certain optimum hardness the quenching treatment need not be so severe, thereby reducing the risk of cracking. This quenching treatment results in a greatly increased hardness (450 to 550 Brinell) due to the formation of the hard constituent, martensite. In this state the iron is much more brittle and the tensile strength inferior to the as-cast material. The maximum advantage from heat treatment is only gained if the hardening operation is followed by tempering. This operation consists of heating the hardened casting at some temperature below the critical point in a lead or salt bath and then requenching in oil or water. By the judicious choice of the tempering temperature various properties may be imparted to cast iron.

In theory, hardened cast iron is unstable, eager to regain its more stable pearlitic condition. Tempering renders the iron more plastic, so encouraging this change. It can thus be understood that as the tempering temperature is raised so the material will more nearly approach the as-cast condition—losing its hardness and regaining its tensile strength. The effect of tempering upon the hardness and tensile strength is shown in Fig. 5. Figs. 6 and 7 show a hardened martensitic iron and a tempered sorbitic iron respectively. Hurst has published some interesting results on ordinary and alloy piston ring irons in which this effect is admirably illustrated. The irons were quenched in oil from 875 deg. C., and very little decrease in hardness was experienced on tempering up to 300 deg. C., whilst usually a large percentage of the original tensile strength was regained. Tempering at higher temperatures than this produced a slow rise in tensile and a rapid fall in hardness. The structure of such irons tempered at 300 deg. C. is sorbitic, while those at high temperatures show a matrix more pearlitic in character.

* Hurst, J. E., Foundry Trade Journal, December 4, 1930, p. 385; December 3, 1931, p. 345.

Air Hardening Cast Irons

Hurst has described an alloy cast iron containing high manganese content which possesses air hardening properties. Manganese lowers the critical quenching speed to such an extent as to render the iron quenchable in air. The analysis of this material is:—T.C., 3.49; Si, 2.8; Ni, 1.0; Cr, 0.57, and Mn, 2.26 per cent.

Very little change in properties is achieved by cooling in air from 750 deg. C. Air hardening from 875 deg. C. increases the hardness value from 226 to 412.

The Effect of Mass on Heat Treatment

The hardening of thin sectioned castings in ordinary and alloy irons is a fairly straightforward task, but the production of uniform hardness in thick sections is a more formidable proposition. The maximum hardness always occurs at the edge of the sample and gradually falls towards the centre of the section. This effect is very pronounced in ordinary irons, but can be modified somewhat by additions of nickel and chromium. Nickel appears to be the most useful alloy in this direction, and experiments conducted by Hurst show that a substantial decrease in this hardness variation is to be gained by the use of 2 per cent. nickel. He has found the difference in hardness between centre and edge on a 1.75-in. bar containing 2 per cent. nickel is 100 Brinell as compared with 160 Brinell found on an ordinary iron.

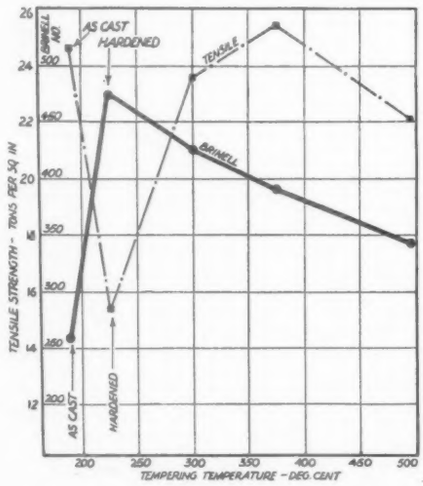


Fig. 5.—Effect of Tempering Temperatures on the Physical Properties of Cast Iron.

Heat Treatment v. Cracking and Distortion

Portevin has suggested the following precautions in the heat treating of steel to prevent cracks, and they may be wisely adapted to cast iron.

(1) The rejection of castings presenting physical defects before quenching.

(2) The use of a preliminary anneal.

(3) Uniform heating.

(4) Quenching at the lowest possible temperature and as slowly as possible consistent with hardness and other properties desired.

(5) The tempering should follow immediately after quenching.

(6) The elimination of sharp angles as far as possible.

In addition to this it is advisable to have the original casting of as close a grain as possible and a carbon content of 2.7 to 3.2 per cent. High carbon, high silicon irons are to be avoided.

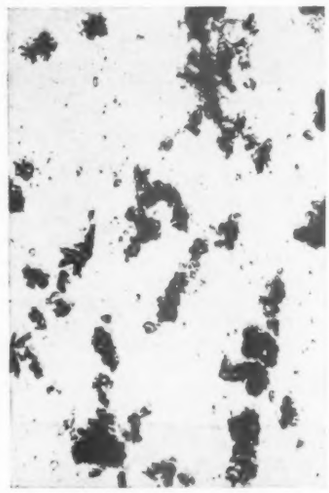


Fig. 4.—Structure of Similar Area after Annealing.

Etched in Picric Acid.
× 200 dias.

When annealing intricate castings for machining purposes it is often advantageous to pack them in small hard coke to reduce distortion.

Specialised Heat Treatment

A number of other forms of heat treatment have been developed during the past few years. Amongst these may be cited nitriding and Shorterising. These processes have been brought forward mainly with a view towards the production of an intensely hard surface on cast iron articles.

Nitriding.—The hardening of steel by means of nitrogen was first discovered by Dr. Fry in 1923, and the application of this process to cast iron materials was first investigated by the Sheepbridge Stokes Centrifugal Casting Company, Limited, in 1928. The majority of the known work on nitrided cast iron is due to Mr. J. E. Hurst and this company.

The process is one of case hardening, and consists of subjecting the cast iron to an atmosphere of dry ammonia gas at a temperature of 500 deg. C. The articles to be treated are packed in a gas-tight box made of heat resisting steel, heated in an electric muffle. Anhydrous ammonia gas supplied from a cylinder is fed into the chamber. During this operation, the ammonia is dissociated into its elements, nitrogen being absorbed by the metal and hydrogen which is evolved

$$2NH_3 \rightarrow N_2 + 3H_2.$$

Dissociation is affected by temperature and pressure—being increased by the former and lowered by the latter. The ideal conditions have been found to be at a temperature of 500 deg. C. and at a pressure of ½ to 1-in. water, giving an ammonia dissociation of 30 per cent. This is maintained by periodical examination of the issuing gas and regulation of the flow of ammonia.

A special alloy cast iron known as Nitricastiron is used in the nitriding process—a typical analysis being: T.C., 2.6; C.C., 1.23; Si, 2.58; Mn, 0.61;

S, 0.07; Cr, 1.69, and Al, 1.43 per cent. This material is susceptible to heat treatment and also shows distinct air hardening properties. For this reason the castings must be annealed and slowly cooled before any machining operations. Nitriding is most favourable when the castings are in the hardened and tempered conditions. Quenching in oil is conducted from 850 deg. C., and is followed by a tempering or stabilising treatment at 600 deg. C. to relieve internal strain. Precautions should be taken to avoid surface decarburisation during these operations. The articles are treated for 60 to 90 hrs., depending on the penetration desired, and then allowed to cool in the atmosphere of ammonia. Surface hardness values of 800 to 1,000 (Vickers diamond) are obtainable with a penetration of 0.01 to 0.018 in. This case shows good coherence with freedom from flaking. Any part of the casting it is desirable to retain may be painted with aluminium paint to render it immune to nitrogen penetration. Microscopic examination reveals very little difference between the case and the core of this material. However, the case etches much more deeply than the core, whilst

Fig. 6.—Martensitic Structure present in Quenched Cast Iron.

Etched in Picric Acid. × 500 dias.

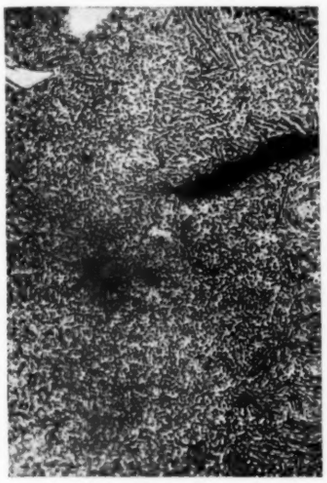


Fig. 7.—Sorbitic Structure present in Tempered Cast Iron.

Etched in Picric Acid. × 500 dias.

at the extreme edge a narrow lighter band is usually present.

Shorterising.—This is a process brought into use during the last few years for the production of hard surfaces on cast iron articles. An oxy-acetylene flame is traversed over the surface of the material bringing the iron to a temperature above its critical point. The iron is then immediately quenched by means of a jet of water or oil arranged to follow the heating flame. Such treatment produces a martensitic case of appreciable thickness. The hardness is usually in the neighbourhood of 600 Brinell. The process finds application in the hardening of gears for lathes, etc., it being claimed that after hardening in this way the gears show none of the fretting usual to those hardened by other processes.

The automobile industry has provided the widest scope for heat treated cast iron. Engineers were quick to realise the advantages of inserted liners over the cylinder block. These are now fitted in almost all automobile engines, either in the wet or dry liner type. They are usually centrifugally cast in an alloy iron containing 3 per cent. Ni and 1 per cent. Cr, being air hardened from 850 deg. C. These liners show roughly half the wear of the ordinary cast iron and offer considerable improvement over the old cylinder block. The high duty conditions of modern engines have increased the wear of all parts considerably, and the use of liners was quickly followed by inserted valve seats. These are used extensively and are machined from centrifugal castings. Alloy irons of the nickel chromium type have proved most useful in withstanding the severe conditions of repeated impact at high temperatures. Heat treated piston rings are in universal use and are made either by the centrifugal or single cast methods. This by no means exhausts the use of heat treated irons. Valve guides, tappets, crankshafts, and camshafts have been produced in heat treated cast iron with remarkable success. The recent adoption of heat treated cast iron instead of steel brake drums has opened up a new field for this material. The heat treatment of such bulky articles is a difficult problem, and the tendency is rather to insert liners of heat treated cast iron. These show remarkable superiority over the steel drums, particularly in their use for heavy vehicles such as omnibuses and freight lorries. Nitrogen hardened cast iron has offered serious competition to ordinary treated iron. Cylinder liners in this material have been used with great success in petrol and Diesel engines. Its superiority is due in part to its resistance to permanent set and corrosive influences—two factors of great importance in cylinder liner wear. Heat treated cast iron is yet in its infancy, and very little published work exists on the subject. There is no doubt, however, that its possibilities are enormous. The development of such irons has definitely placed that Cinderella among the metals on an equal footing with any other metallurgical product, and has in no small way rendered possible the speed of this modern age.

New Vacuum Furnace for Oxygen Estimation

G. Thanheiser and E. Brauns, in Report No. 112 of the chemical sub-committee of the Verein deutscher Eisenhüttenleute, which is published in the "Archiv für das Eisenhüttenwesen," describe the construction and employment of a new vacuum furnace for the determination of oxygen in steel. The furnace operates on the hot-extraction method, and gives reliable values, being also probably suitable for the determination of other gases in steel. From an investigation of the effect of the manganese content of the steels on oxygen determination, it was found that this influence is largely determined by the working conditions, particularly the cooling rate. Results obtained with the new furnace are in good agreement with those obtained with the apparatus hitherto current.

Rustless Steels in the United States

PRODUCTION IN 1935

In an article entitled "Rustless Steels," by Mr. T. W. Lippert, published in a recent issue of "The Iron Age," the author points out that both primary and secondary producers have co-operated to give a true picture of 1935 finished steel production segregated into types of products and analyses. As in previous years, one primary and two secondary producers refused to submit figures, but certain deductions served effectively to establish the activities of these three mills. Thus the 67,227 tons of ingots shown in Table I as the total 1935 output is believed to be accurate to within several per cent.

Table I.—*Production of Corrosion and Heat-Resisting Steel in the United States* (1933–1935).

(Net tons.)

	1933.	1934.	1935.
Ingots:			
18 Cr and 8 Ni	19,620	24,818	33,114
25 Cr and 12 Ni	—	—	2,827
12 to 14 per cent. Cr (approx.)	7,401	8,658	8,340
16 to 18 „ „	4,969	6,242	11,256
18 to 30 „ „	—	—	1,306
All others (Cr and Cr-Ni)	4,262	3,977	10,384
Total	36,252	43,695	67,227
Castings:			
18 Cr and 8 Ni	352	387	446
25 Cr and 12 Ni	—	—	760
12 to 14 per cent. Cr (approx.)	36	164	148
16 to 18 „ „	225	86	288
18 to 30 „ „	—	—	262
All others (Cr and Cr-Ni)	2,026	2,218	2,054
Not allocated	54	19	13
Total	2,693	2,874	3,971
Grand Total (ingots and castings)	38,945	46,569	71,198

The Influence of Special Elements on the Physical Properties of Cast Iron

(*Concluded from page* 419.)

magnetism, permeability, and saturation, after an initial increase, remain constant or again decrease. The greater the decrease in silicon for a given addition of nickel, the more intense the effects observed. In a series of irons containing 3 per cent. carbon, 2.3 per cent. silicon, and copper varying from 0.56 to 1.92 per cent., there is a slight rise in coercive force and a slight decrease in permeability with increase in copper content, and a similar result is obtained with irons containing 3.75 per cent. carbon, 2.5 per cent. silicon, and 0.24 to 1.43 per cent. chromium, except that the increase in coercive force is greater.

In general, the magnetic properties of cast iron largely depend on the nature of the structure of the iron, and the influence of alloy additions on the magnetic properties of cast iron, either cast or heat-treated, is an indirect one, depending on how such additions affect the ultimate structure of the material.

A new company has been registered under the name of Reynolds Rolling Mills, Limited, for the manufacture of aluminium and magnesium-alloy sheets and strip and allied products, as an extension of the aluminium-alloy products in tubes, bars and sections already being made by the Reynolds Tube Company, Limited, at Hay Hall Works, Tyseley, Birmingham. The company is a private one, the capital, which is registered at £200,000, being subscribed for by Tube Investments, Limited, and High Duty Alloys, Limited.

Large Universal Grinding Machine

There is an ever-increasing demand for heavy-duty anti-friction bearings. Power consumption is a daily problem, and frictional resistance in bearings must always be a very vital factor; further, it must be borne in mind that such friction is practically constant, whether the machine is running light or fully loaded, and in the case of a rolling mill, or even a heavy-duty machine, friction losses represent a substantial addition to power costs.

During the past few years the anti-friction bearing has been developed to meet the heaviest duties, and there are few firms who have done more to foster such development than British Timken, Limited, the well-known manufacturers of tapered-roller bearings, the fundamental principle of which embodies the ability to absorb a combination of thrust and radial load. Precision in manufacture is, of course, a first consideration, and when it is understood that the variation of the complete assembly must not exceed one and a-half thousandths of an inch, it will be appreciated to what narrow limits the components must be made.

Grinding is obviously a vital factor in the manufacture of the anti-friction bearing, and upon that grinding not only the precision, but also the economy of production is largely dependent. The demand for bearings of exceptional size had perforce to be met, but there was no grinding machine of a size and of suitable design to meet the requirements. Neither could such design be lightly determined; however, the technical engineers of British Timken, Limited, working in close conjunction with the Churchill Machine Tool Company, Limited, evolved a design to meet the requirements, though it took them approximately two years to achieve their purpose. The machine, which, by the courtesy of British Timken, Limited, was recently inspected by our representative, was built by the Churchill Machine Tool Company, Limited, and furnishes very striking evidence of the value of user and manufacturer combining to work for a common end.

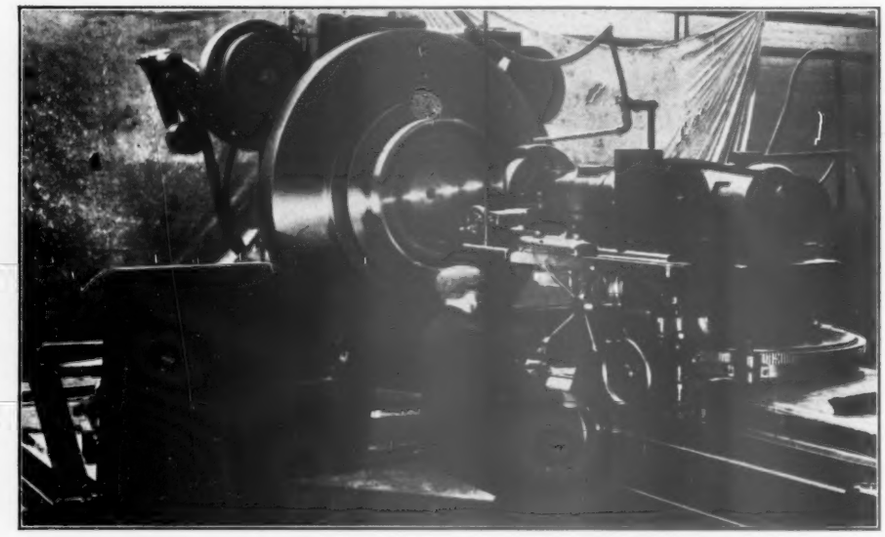


FIG. 1.—VIEW OF MACHINE IN OPERATION.

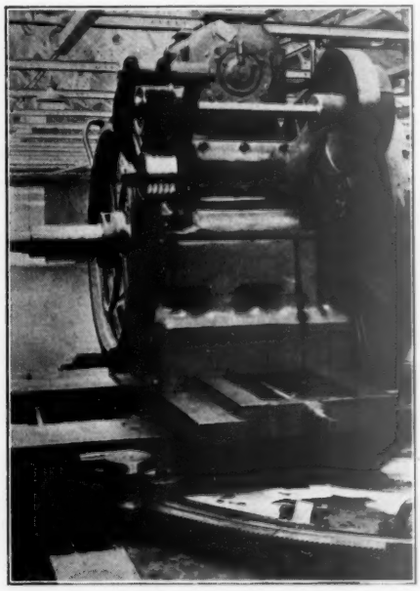


FIG. 2.—VIEW OF WORKHEAD SHOWING ROPE DRIVE.

The weight of the complete machine, shown in the accompanying illustrations, is 45 tons, the height from floor to wheel centre being 6 ft. 8 in. and the faceplate 70 in. dia. The workhead body vee ways are 4-ft. centres by 20 ft. 7 in. long. The workhead spindle bearings are 8 in. dia. by 11½ in. long for the front spindle and 7½ in. dia. by 11½ in. long for the rear spindle. The wheelhead body vee ways are 3-ft. centres by 13 ft. 4 in. long. Three wheelheads are available, 2-L.H., with extensions 24 in. and 12 in. long, and 1-R.H. with short extension. The reversible automatic feed to the wheelhead is variable between 0.00025 in. and 0.001 in. The hydraulic traverse operates at 3 in. to 36 in. per min. The grinding wheels are 4 in. wide on the face, and wheels of 24 in. and 18 in. dia. may be employed.

The workhead is driven at the rear end by a large-diameter Texrope pulley with an adjustable jockey pulley for tensioning. The drive, as also the wheelhead, is detachable, so that the machine may be raised for a larger swing should this be necessary at a later date. The workhead has compound adjustments for dealing with various sizes and types of races. The oscillating slide, which is operated hydraulically, has an oscillation of 10 deg. each side of the centre line.

The wheelhead slide is operated hydraulically, and is mounted on a swivel base so that it can be turned through a complete circle, the feed motion operating at any angle of the head as set. The motor driving the wheelhead carries a vee-rope pulley on either side, and is thus adaptable for driving either of the three wheelheads. Automatic cross feed is provided to the grinding wheelhead for use when the head slide is traversing. The cross feed will operate in either direction, for internal or external grinding.

The workhead is driven by a 10-h.p. reversible four-speed motor, which, with change pulleys, gives eight spindle speeds, ranging from 5 to 31 r.p.m. The wheelhead is driven by a 35-h.p. motor, and through change pulleys spindle speeds are obtained of 875 and 1,167 r.p.m. to suit wheels of 24 in. and 18 in. dia. and give a surface speed of 5,500 ft. per min. The hydraulic traverse to the wheelhead and workhead and the oscillating motion of the last named are each operated by a 5-h.p. motor. Oil is supplied under pressure to the workhead and wheelhead slides by a pump driven by a ½-h.p. motor.

All the motors are controlled by means of push-button-operated contactor starters, the gear for the 35- and 10-h.p. motors being housed in one multi-control panel adjacent to the machine and controlled from a station mounted on the body of the machine. In this station are seven push-buttons, five for the workhead motor and two for the wheelhead motor. For the workhead motor the push-buttons are for each speed which can be selected at will. For the wheelhead motor the push-buttons are for starting and stopping. A very practical feature of the machine is that a meter in the wheelhead motor circuit indicates constantly the amount of current flowing. If the grinding wheel becomes glazed or clogged with metal, the meter at once indicates this by reason of the extra consumption of current. The motors were supplied by the Metropolitan-Vickers Electrical Company, Limited, and the switchgear by Brookhirst Switchgear, Limited.

The machine has now been in operation for several weeks at the Cheston Road Works, Birmingham, of British Timken, Limited, and at the present moment is working with experimental grinding wheels. It is stated that even on these wheels the reduction in grinding time, as compared with the machines used hitherto, is amazing. As a rough estimate, it is claimed that as much as 75 per cent. saving in grinding time has been effected.

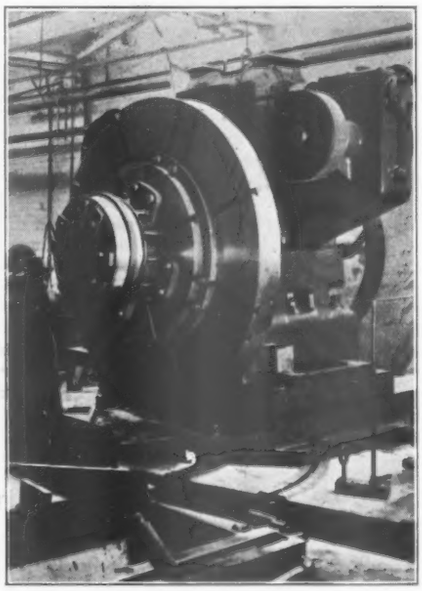


FIG. 3.—OBLIQUE VIEW OF WORK-CARRYING FIXTURE AND FACE PLATE.

An Extension of the **STANTON**

Metallurgical Service

CONSULTATIONS with an expert in foundry technique who will, if desired, visit your own foundry, are a feature of the extended advisory service offered by the Stanton Company. Such visits are additional to, and quite distinct from, the ordinary calls made by sales representatives, the subjects discussed covering the whole field of foundry practice.

All queries, whether they require a personal visit or can be answered by post, will be attended to promptly and individually by a qualified metallurgical staff. The service is intended to benefit both users and producers of pig-iron by helping to improve the properties of cast-iron, so extending its field of use.

Both as ironfounders whose cast-iron products are used in all parts of the world, and as the largest producers of foundry pig-irons (for sale) in Great Britain, the Stanton Company have many years' experience of metallurgical problems. Through the medium of the advisory service this experience is placed at the disposal of the foundry industry.

Much information constantly needed by the foundryman appears in concise form in the Stanton pig-iron handbook which will gladly be sent on request. It contains useful cupola data and photographs of fractures, microphotographs and analyses of all Stanton pig-irons—including Stanton, Holwell and Rixons (W'bro') brands.

THE STANTON IRONWORKS COMPANY LIMITED
Near NOTTINGHAM

Creep Properties of Cast Iron

The discussion on the Paper on "The Behaviour of Five Cast Irons in Relation to Creep and Growth at Elevated Temperatures,"* by H. J. TAPSELL, A.C.G.I., M. L. BECKER, Ph.D., B.Met., and C. G. CONWAY, B.Sc. (National Physical Laboratory), presented at the Annual Meeting of the Iron and Steel Institute in London recently, was opened by MR. J. G. PEARCE, who said there was no attempt to determine the creep conditions with reference to systematic changes in composition or structure. Of the five materials tested, the first was a straight cast iron of a type which was very widely used in the construction of engineering castings, and not, of course, designed in any way whatever to resist heat. The second was an alloyed cast iron of the low-alloy type used for special castings. Those two served to provide a datum, and in the second iron regard must be paid to the fact that it had a higher silicon content than the first, in spite of the allowance that had to be made for the alloy additions. The three remaining irons were comparatively new. Silal had been described to the Iron and Steel Institute in 1931,[1] and its properties had since been confirmed in several other countries.[2] The tendency to growth and oxidation was reduced by using a high-silicon ferritic matrix with a low carbon content and finely divided graphite, and it was interesting to note that Gough and Pollard[3] had recently given to the Institution of Mechanical Engineers some very interesting figures relating to the fatigue properties of this material, which had an endurance ratio of virtually unity. Niresist was now a well-known austenitic iron containing nickel-copper-chromium. Nicrosilal was also rendered austenitic by nickel-silicon-chromium, and had been described to the Institute in 1932.[4]

Better Materials now Available

In the experiments given in the present Paper, it was desired to use commercially-made materials, in spite of the fact that so far as the three heat-resisting irons were concerned the makers at that date had comparatively little experience, while to-day he thought that the materials would be more uniform and the results better. The relative instability of certain compositions forming the austenite at medium temperatures was known, and it was recognised that the first batch of Nicrosilal tested might give some difficulties in that respect, but it was believed that the second batch would be quite stable; however, in the long-period tests which were used by the authors it did suffer to some extent at the temperatures used, and the point which he would like to make in particular in that connection was that the demand which had to be met by special irons of this type arose in furnace and other plant operating at substantially higher temperatures than those originally used in the Paper, which were governed by the requirements of modern steam plant. It was gratifying, therefore, that it was found possible to include some tests at 850 deg. C., at which temperature, of course, austenite was quite stable. At the lower temperatures growth mainly arose from graphitisation, and it might be recalled that Benedicks gave two per cent. as a possible volume increase due to this. At higher temperatures oxidation also proceeded, and the dimensional change arising therefrom could be very much more serious. At the lower temperatures it was clearly an advantage to heat-treat the material in such a way as to decompose the pearlitic cementite.

The authors had remarked that Silal had a creep and growth resistance of the same order as the ordinary and low-alloy irons after heat-treatment, which was tantamount to suggesting that it was equivalent to the growth of an iron after the capacity for growth had been removed, at any rate so far as temperatures were concerned at which oxidation did not occur. It must be borne in mind, however, that the heat-treatment of castings was not always practicable, and that in any case where the pearlitic carbide was broken down the strength was reduced, as was well shown in the Paper. Such treatment, while it was actually carried out in suitable cases, was not for general application.

Broadly speaking, said Mr. Pearce, the best type of heat-resisting iron to suit a given set of conditions was a matter of choice from a variety available, and the data given in the Paper would be of great assistance in adding to what was already known; and it was, incidentally, of a type for which frequent requests were received. Making due allowance for the factors mentioned, the results generally fell into line with expectations.

He would like to conclude by referring to the figures which had been given by an independent worker, Dr. Inglis, for various applications, but not primarily with regard to steam plant conditions.[5] Dr. Inglis gave a series of temperatures at which serious deterioration occurred due to growth and scaling, as shown below. The "ordinary cast iron" was presumably an iron with a mixed structure of ferrite and pearlite, while the 1 per cent. chromium cast iron was a well-known type of heat-resisting iron.

	Temp. at which serious deterioration occurs (growth and scaling).	Temp. at which appreciable scaling occurs.	Recommended maximum for practical use.
	Deg. C.	Deg. C.	Deg. C.
Ordinary cast iron	500	500	450
Pearlitic cast iron	650	500	550
1 per cent. chromium cast iron	750	550	600
Silal (4 to 10 per cent. Si)..	900	800	750
Nicrosilal and similar high Cr and NiCr cast irons ..	No change up to 1,000	900	950

Experimental Material Not Typical

MR. W. T. GRIFFITHS said that the Paper contained the report of a series of valuable observations of a type which had now come to be expected regularly from the co-operation between the engineering and metallurgical departments at the National Physical Laboratory. As Mr. Pearce had said, it provided information for the first time on a range of cast irons in regard to the particular properties examined for which everyone had been waiting, and was in line with a large amount of data of a similar character which the National Physical Laboratory had continually supplied.

He thought, therefore, that it was rather a pity, even taking account of the time when the experiments were initiated, that the authors should refer to their irons as "typical." Early in the Paper they said that "five typical irons were chosen," and then they went on immediately to point out how they departed from being typical in various respects. In particular, he thought it was a pity that they had referred to what they called throughout the Paper a nickel-chromium cast iron as typical. As one who had had not a little to do with the development of alloy cast irons in this country, he wondered of what it was typical. It was certainly not typical of what were called the alloy high-quality cast irons of to-day, or such as had been in existence for several years, and, with its silicon, phosphorus, nickel and chromium contents, it was certainly not typical of any iron which would be suggested by anybody, even for service which would only occasionally reach temperatures above normal.

The matter was of more importance than it would be if it concerned only the present Paper. Reliance was placed on the National Physical Laboratory to provide data, and it was desirable to have the information as quickly as possible. We spent in this country a large amount of money on research, and financial support was given both by the Government and the industry. With all due deference to those who were responsible for initiating the present work, he would appeal to them to take every possible precaution to see that the materials employed were such that conclusions could be drawn from the work when the results were obtained, not only from the point of view of saving money, but because those engaged in industry could not afford to spare the time which their friends at the National Physical Laboratory were giving to the work, because they so urgently needed the results, and the sooner that they could draw satisfactory conclusions the better.

Material Selection

The Paper was of particular interest in its relationship to the effect of selection on materials, and cast irons in particular, which might have to resist high temperatures. In the so-called pearlitic or α-iron cast irons, there were two things which had to be watched. Where one was not going to use much silicon, as the President and others had shown, and where that was not going to be a feature of the iron, it was as well to keep that content down as low as possible. He did not agree with the suggestion that the silicon content might be raised to counteract the influence of the chromium; that was the wrong way to go about it in an iron for use at high temperatures. There were many other ways of counteracting the effect of the chromium, and a high silicon content was not the way to do it; and by "high" he meant up to the two per cent. referred to in the Paper. Of course, as Mr. Pearce and his colleagues had shown so admirably, when the silicon content was raised up to four, five or six per cent. an entirely different effect came in, namely protection against oxidation and penetration of oxidation, which resulted in the low growth and admirable properties of Silal. On the other hand, in regard to the austenitic or γ-iron cast irons, the effect of silicon had to be watched in an entirely different connection. In the laboratory with which he was associated, they had been studying the question of the stability of austenite in cast irons over some months. The results had not yet reached a stage when they could be reported on, but they hoped to have the privilege of reporting them to the Institute at some future date.

Niresist and Nicrosilal

Already it seemed clear, however, that if the silicon were increased to produce a cast iron of the type of Nicrosilal it was necessary to do other things with regard to the composition as well, because the effect of the silicon seemed definitely to be in the direction which the authors had shown, of breaking down the austenite and giving growth effects, the production of martensite or sorbite. It would be observed from the results given that that breakdown was not noticeable in the Niresist iron, simply, he would suggest, because the silicon content was of a different order. With Nicrosilal there was a

(*Concluded on page 428.*)

* FOUNDRY TRADE JOURNAL, May 14 and 21.

1 Norbury and Morgan, Journal of the Iron and Steel Institute, 1931, No. 1, p. 413.

2 Thyssen, Journal of the Iron and Steel Institute, 1935.

3 Gough and Pollard, Proceedings, I.Mech.E., 1935.

4 Norbury and Morgan, Journal of the Iron and Steel Institute, 1932, No. 2, p. 301.

5 Inglis, Transactions, Soc. Glass Technology, 1933, Vol. 17.

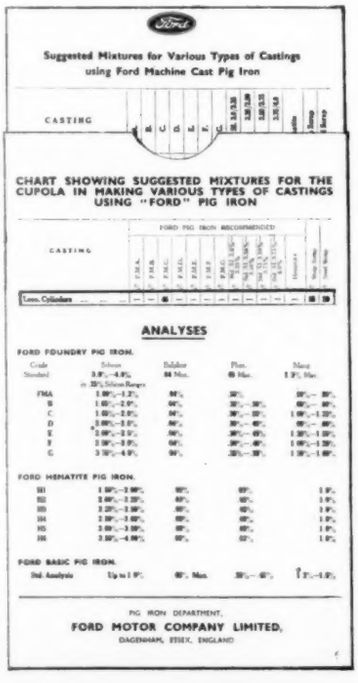
CUPOLA PRACTICE AND METAL CONTROL

IN the Foundry of Ford Motor Company Limited, at Dagenham, metal control is one of the cardinal points of foundry practice. No expense is spared in metallurgical research, in any unit of the Ford organisation, and Ford foundry practice is therefore the concrete, logical embodiment of the latest developments.

Ford Motor Company Limited have themselves derived such benefit from this alliance of science and practice that they instituted similar service when they commenced to market their foundry pig iron, placing their metallurgical research-data at the disposal of any of their customers who cared to avail themselves of such valuable information.

Striking results have been obtained for a number and variety of customers, particularly in connection with complicated, intricate castings which normally furnish much difficulty, but in which class of foundry work Ford Motor Company Limited have such wealth of experience upon which to draw that difficulties of this nature are easily overcome.

A chart recently issued shows typical cupola mixtures, using Ford pig irons, and gives data upon cupola operation, and analyses of Ford pig irons. Foundrymen can obtain a copy of this chart upon application.


Suggested Mixtures for Various Types of Castings using Ford Machine Cast Pig Iron

CASTING

CHART SHOWING SUGGESTED MIXTURES FOR THE CUPOLA IN MAKING VARIOUS TYPES OF CASTINGS USING "FORD" PIG IRON

CASTING — FORD PIG IRON RECOMMENDED

ANALYSES

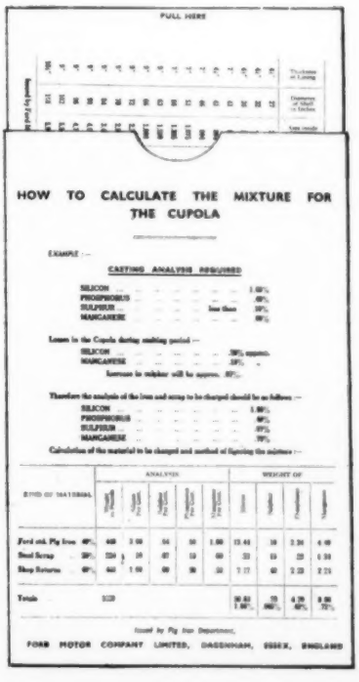
FORD FOUNDRY PIG IRON.

FORD HEMATITE PIG IRON.

FORD BASIC PIG IRON.

PIG IRON DEPARTMENT,
FORD MOTOR COMPANY LIMITED,
DAGENHAM, ESSEX, ENGLAND

We cordially invite foundrymen to visit the Ford Works, at Dagenham. Appointments can be made, at any time, with the Pig Iron Sales Dept.,


HOW TO CALCULATE THE MIXTURE FOR THE CUPOLA

EXAMPLE :—

CASTING ANALYSIS REQUIRED

Issued by Pig Iron Department,
FORD MOTOR COMPANY LIMITED, DAGENHAM, ESSEX, ENGLAND

FORD MOTOR COMPANY LIMITED, DAGENHAM, ESSEX, ENGLAND

breakdown because the silicon content was increased and its effect was not counteracted by austenite-forming elements at the same time. He believed that it was possible to stabilise austenite with high silicon by taking suitable precautions.

There was another interesting feature which emerged, namely, that the breakdown to martensite did not take place at the high temperatures. A change certainly went on at the high temperatures, but the transformation from austenite to martensite, which was accompanied by an expansion, really occurred on cooling at temperatures of the order of 150 deg. C. or 200 deg. C. That might be of importance with regard to the stability of shape and lack of distortion in castings subjected to repeated heating and cooling.

There were one or two minor points which he would like to mention. He noticed the references which had been made to the development of the cast irons in question for high temperature service, but he did not know that Niresist was ever developed for high-temperature heat-resisting purposes; in fact it was not developed for heat-resistance at all. It was originally suggested as a corrosion-resisting cast iron, an austenite cast iron which could be made cheaply and which would provide a degree of corrosion resistance. It had proved of service for high-temperature applications, but personally he would not be inclined to recommend a very extensive use of that material, or indeed of any of these austenitic cast irons at the present stage, for temperatures of the order mentioned in the Paper or above. For those higher ranges of temperature, unless there was very complete support for the cast-iron structure and fairly complete immobility of that structure, the field was one more for the heat-resisting steels and other heat-resisting alloys in which the Institute was interested.

Preliminary Ageing

The effect of preliminary ageing was extremely interesting. While he agreed with Mr. Pearce that the heat-treatment of cast irons or the annealing of cast irons was not a thing one always wanted to do, yet if it were possible, as the authors suggested, by this preliminary ageing to give to the low-alloy-content cast irons in question properties at high temperatures which were satisfactory from a creep point of view, then he thought that it might be worth while following up the suggestion, because one could obtain properties at ordinary temperatures in those cast irons which were of value, and they suggested that some of their properties, and particularly toughness and freedom from brittleness, might be made available at high temperatures if it were possible to get rid of the factor of growth. That growth could be diminished by suitable variation of combination, and he would not like the discussion to terminate without some reference to the fact that the so-called alloy cast iron, the nickel-chromium cast iron referred to in the Paper, was certainly not typical of anything that would be suggested either for engineering or for high-temperature service.

Unbalanced Sulphur

DR. A. L. NORBURY said that the authors' results agreed very well amongst themselves and were very convincing. Their tests were not, of course, carried out in an atmosphere of superheated steam, but he would like information as to the nature of the atmosphere and the extent to which air circulated round the specimens during test and caused growth due to internal oxidation.

He would like to make some observations on the compositions of the irons tested, as given in Table I of the Paper. The ordinary iron was a low-manganese cast iron, and its manganese content of 0.28 per cent. was insufficient to neutralise the 0.12 per cent. sulphur present. In cast iron about 0.3 per cent. manganese in excess of that required to form manganese sulphide was necessary to neutralise the sulphur. Some of the sulphur in the iron in question was therefore not neutralised and would have a powerful effect in stabilising combined carbon. That would account for the high combined carbon content of the 1.10 per cent. in Table I, and would also retard the decomposition of that combined carbon into graphite during the creep tests and during annealing. If the manganese content of that iron had been about 0.5 per cent. the combined carbon content would have been lower and it would have decomposed more rapidly on heating. He was not suggesting that the iron was not a typical one, but merely calling attention to certain characteristics of its composition.

The nickel content of the Niresist was higher than the usual 14 per cent. That difference was important from the point of view of the stability of the austenite, and also, of course, it was important economically.

Properties of Nicrosilal

With regard to the composition of Nircosilal tested and the effect of composition on its breakdown on heating at 450 deg. C. and 538 deg. C., attention was drawn to this breakdown in the original Paper on Nicrosilal,[6] and it was stated that compositions "containing less than about 5 per cent. of silicon and more than about 17 per cent. of nickel were stable and were not hardened even after several 15-hr. annealings round about the most dangerous temperature," about 500 deg. C. The authors had, however, shown that such compositions did decompose to a certain extent on the rather more prolonged heatings which they gave them, for example, 40 days at 538 deg. C. The suggestion was that a still further reduction in silicon content and increase in nickel content would produce a composition of Nicrosilal which would not break down under those conditions.

In conclusion, he would like to say that his observations had been on points of detail only, and he wished to express his appreciation of the accuracy and usefulness of the authors' results and of the impartial manner in which they had presented them.

MR. F. W. HARBORD said he understood Mr. Pearce to say that the ordinary cast iron was typical of what was used for ordinary engineering castings, and he hesitated to suggest that that was not the case, in view of Mr. Pearce's wide experience, but it did seem to him that that iron was not what he would call an ordinary grey foundry iron, and he would have assumed that for most engineering purposes, certainly in his own days, it was customary to use a grey iron. In the case dealt with in the Paper, one-third of the carbon was in the combined condition, the silicon was 1.27 per cent., the sulphur 0.12 per cent., and the manganese 0.28 per cent. He would expect an iron of that sort to give a mottled fracture, and it would not be typical of the ordinary foundry iron used in engineering castings. He might be wrong there; he only asked for information. In any case, it would have added to the interest of the Paper if the authors had interposed another iron between that and the Silal. It would have been interesting had the authors interposed a typical foundry iron with a little over 2 per cent. silicon and with the greater part of the carbon in the non-combined condition.

Welding Aluminium Steels

A Paper in "Dominion Oxwelding Tips" deals with the welding and cutting of high-chromium steels. Welding of high-chromium steels has always presented certain difficulties owing to the fact that chromium at high temperatures has a very definite affinity for both oxygen and carbon. One of the first principles in welding such steel is close flame control. An oxidising flame would remove chromium from the metal as chromium oxide, while the use of an excess acetylene flame would promote the formation of chromium carbides. A neutral flame is therefore essential, while other factors also need careful attention. The Paper lists these factors, and gives full particulars of practice.

6 Journal of the Iron and Steel Institute, 1932, 2, p. 318.

Students' Corner

SECOND SERIES

Cupola Practice—*(continued)*

Q. 11.—*What should be the composition of a cupola slag?*

A.—Cupola slags may be summarised as a compound of acids and bases, which have a strong chemical affinity for each other. The approximate analysis of a typical cupola slag is as follows: lime 25 per cent., ferrous oxide 5 per cent., alumina 10 per cent. and silica 49 per cent. Neutral substances (neither acid nor basic) such as calcium sulphide and calcium fluoride may also be present.

Q. 12.—*When the cupola is lit and the blast turned on what reactions occur?*

A.—The blast, being atmospheric, is composed of 77 per cent. nitrogen and 21 per cent. oxygen, the remaining 2 per cent. being aqueous vapours. The air, or blast, passing through the tuyeres comes into contact with the burning coke, and by increasing the rate of combustion converts it to an incandescent mass, with a temperature more than sufficiently high to liquify the iron. As the iron melts, it percolates through the partly-burned coke to the bottom of the cupola. Intense heat is thus imparted to the iron, which is retained in a liquid condition for a considerable time. The highest possible temperature in the melting zone is about 1,600 to 1,700 deg. C. The oxygen of the air combines with the carbon from the coke form a volume of carbonic acid gas equal to that of its constituents. Thus 30 ozs. of oxygen, requiring about 140 ozs. of air combine with 12 ozs. of carbon to form 44 ozs. of carbonic acid gas.

Q. 13.—*If the cupola is only a 50 per cent. efficient melting unit, how is the loss accounted for?*

A.—In cupola practice a large amount of heat is lost by radiation; incomplete combustion; gases ascending through the stack; and fluxing the coke-ash, silica-sand, dirt, etc., to form the slag. Therefore, between the theoretical heat value and actual practice a margin of about 50 per cent. for the various losses must be assumed.

If a cupola is a 50 per cent. efficient melting unit, it should melt one ton of iron with 166 lbs. of coke, and 22,000 cu. ft. of air. This is seldom done, mainly due to the coke being only partially burnt to carbon dioxide, hence, in practice, 200 lbs. of coke, and 30,000 cu. ft. of air would be necessary to melt one ton of ordinary iron with a sufficient superheat to run castings.

Q. 14.—*Is the metal charged into the cupola of the same composition after being melted?*

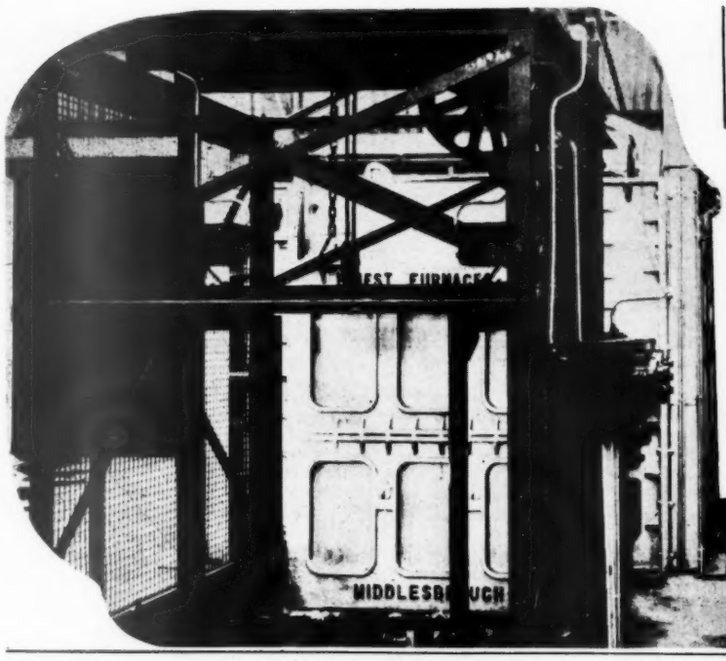
A.—No. When calculating the composition of the cupola charges to produce castings to a definite analysis, an allowance must be made for, (1) a slight loss in silicon, graphitic carbon, and manganese, and (2) an increase in combined carbon and sulphur.

The changes in the constituents of an iron during six remelts were as follow:—

Graphite carbon was reduced from 2.73 to 2.08 per cent. Combined carbon was increased from 0.60 to 1.28 per cent. Silicon was reduced from 2.48 to 1.16 per cent. Sulphur was increased from 0.04 to 0.20 per cent. Manganese was reduced from 1.09 to 0.36 per cent. Phosphorus was reduced from 0.31 to 0.28 per cent.

Hence the metal after each remelt is finer in grain, of higher density, harder, and the solid contraction is increased. If the remelts are carried further the result would be a white iron.

(To be continued.)



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This Week's News in Brief

Trade Talk

DARLINGTON FORGE report that both the forge and foundry departments are now in regular and satisfactory production.

THE DANISH STATE RAILWAYS ADMINISTRATION has placed an order with Dorman, Long & Company, Limited, Middlesbrough, for 5,500 tons of rails, valued at £41,250.

ANOTHER German warship, the 25,000-ton "Kaiserin," was raised at Scapa Flow on May 14 by Metal Industries, Limited. Work began on this wreck last autumn. The vessel is 564 ft. long.

HARLAND & WOLFF, LIMITED, of Belfast, and Short Bros., of Rochester, have concluded an agreement under which the two firms are to form a new company to construct aircraft, both land and marine types, at Belfast.

THE DUNDEE CHAMBER OF COMMERCE is celebrating its centenary this year, and amongst many Dundee business firms which originated 100 years ago or more is James P. Low & Company, Limited, Monifieth Foundry, which was founded in 1811.

ONE OF THE HEAVIEST LOADS ever taken by road in this country was seen at Birmingham recently, when part of a new generating set, weighing 100 tons, was moved from the Witton works of the General Electric Company, Limited, to the Hams Hall power station.

A NEW PUBLIC COMPANY has been formed called Electrical Switchgear & Associated Manufacturers, Limited, with a nominal capital of £225,000, in 100,000 preference £1 shares and 250,000 ordinary 10s. shares, to acquire not less than 90 per cent. of the issued capital of Brookhirst Switchgear, Limited.

THE GRIMESTHORPE FOUNDRY of the English Steel Corporation recently completed two 100-ton castings, a 65-ton casting for a big anvil block and also a 58-ton cast steel main frame, for Davy Bros., Limited, to be used for a hydraulic moulding press.

BOILER-HOUSE AUXILIARY PLANT for the new generating station for Fulham Borough Council is to be supplied by James Howden & Company, Limited, Glasgow, and Malcolm & Allan, Limited, also of Glasgow, are to supply auxiliary switchgear and cable.

LORD LONDONDERRY is to visit Middlesbrough next month in order to inaugurate the new pipe-making plant which is approaching completion at the Ormesby Ironworks of Cochrane's (Middlesbrough) Foundry, Limited. The firm specialises in the manufacture of spun-iron pipes under the patented Mairy process, and the largely increased demand for the company's products for export has led to the construction of new plant, which embraces six additional centrifugal machines to be operated under this process.

SUBJECT TO the settlement of certain points of detail, the Admiralty have decided to entrust the construction of the nine Tribal-class destroyers, 1936 programme, to the following firms:—Two vessels to Swan, Hunter & Wigham Richardson, Limited, Wallsend-on-Tyne (with machinery by the Wallsend Slipway & Engineering Company, Limited); two vessels to W. Denny & Bros., Limited, Dumbarton; two vessels to Parsons Marine Steam Turbine Company, Limited, Wallsend-on-Tyne (hulls by Vickers-Armstrongs, Limited, Walker-on-Tyne); two vessels to Scotts Shipbuilding & Engineering Company, Limited, Greenock; and one vessel to A. Stephen & Sons, Limited, Govan.

RAILWAY STATISTICS for the calendar month of January and the four weeks ended January 25, 1936, which have now been published by the Ministry of Transport (H.M. Stationery Office, 2s. 7d. post free), show that the total tonnage of freight conveyed (excluding free-hauled traffic) in the four weeks ended January 25 was 22,851,282, an increase compared with the corresponding four weeks of 1935 of 1,062,675 tons, or 4.9 per cent. The freight-train receipts amounted to £6,956,962, an increase of £318,055, or 4.8 per cent. The freight-train miles run were 233,763 more than in the corresponding period of 1935, an increase of 2.3 per cent. The average train-load increased from 125¾ to 130 tons, but the net ton-miles per engine-hour decreased from 453¾ to 435½.

Personal

SIR ROBERT HADFIELD has been elected a foreign member of the Norwegian Academy of Science and Letters at Oslo, in Group I, for mathematical and natural sciences. The number of members of the Academy is limited in Group I to 110 Norwegians and 100 foreigners.

MR. AND MRS. ROBERT GROGGINS, of Norcot, Holcombe, near Bury, Lancs, entertained about 50 guests at a dinner and dance at the Masonic Hall, Bury, on May 15, to celebrate their silver wedding. Mr. Groggins founded the firm of Robert Groggins, Limited, textile machinists, of Elton, Bury, 14 years ago, of which firm he is the managing director. He is also managing director of Hacking & Company, Limited, ironfounders, of Bury.

ON THE OCCASION of the 50th anniversary of their wedding day, Mr. and Mrs. J. J. McClelland are entertaining all the members of the Wales and Monmouth Branch of the Institute of British Foundrymen to a supper dance at the Park Hall, Hill Street, Newport. This is to take place on Saturday, June 6, and we are sure that the innumerable friends of Mr. and Mrs. McClelland, spread over two continents, will join us in congratulating them on the attainment of the golden wedding and wishing them a continuously happy future.

MR. A. H. GUY, the President of the South African Engineers' and Founders' Association and managing director of the Eclipse Tube Mill Liners (Prop.), Limited, of Benoni, South Africa, arrived in London last Monday. His address is c/o the Standard Bank of South Africa, West End Branch, 9, Northumberland Avenue, London, W.C.2. He will participate in the Glasgow Conference of the Institute of British Foundrymen. Mr. A. H. Moore, of the Standard Brass Foundry, Benoni, honorary corresponding member of the Council of the Institute of British Foundrymen, accompanied by Mrs. Moore, also arrived by the same boat.

Wills

BEARDSHAW, WILLIAM, of Sheffield, head of J. Beardshaw & Son, Limited, steel manufacturers	£15,672
TALBOT, F. J., of Sheffield, chairman of Ibbotson Bros. & Company, Limited, Globe Steel Works	£186,079

Obituary

MR. WILLIAM ANDERSON, a cashier of Shanks & Company, Limited, of Glasgow, died on May 22.

MR. GEORGE WILLIAM PETTIFER, for over 25 years pipe shop foreman at the Staveley Coal & Iron Company, Limited, has died at the age of 64.

MR. CEDRIC HOWELL, who died on May 20, at the age of 78 years, was for many years connected with the firm of William Jessop & Sons, Limited, steel manufacturers, Sheffield. He joined the firm in 1878, and before he retired held the position of secretary.

WE VERY SINCERELY REGRET to announce the death of Mr. Emil Ramas, one of the outstanding figures in international foundry activities. Mr. Ramas was amongst the first group of distinguished foundrymen to attend the 1922 Conference of the Institute of British Foundrymen, as the principal French delegate, was immediately singled out as a personality worthy of recognition, and was made an honorary member of the Institute. At this meeting the seeds of international foundry co-operation were sown, and when, in 1926, Mr. Ropsy called a meeting of all the Presidents of the European foundrymen's associations in Brussels to consider the formation of an international committee, Mr. Ramas was present to lend his influential support. When a few years ago dissatisfaction was evident amongst the members of the Association Technique de Fonderie, he was recalled from his position of honorary President again to resume the reigns of office. His efforts at reorganisation were immediately successful. On the occasion of the International Conference held in France in 1932, when Mr. A. Harley was President of the International Committee, Mr. Ramas was honoured by the bestowal of the gold medal of the Association. His efforts on behalf of the French foundry industry were also recognised by the French Government, and he was a Chevalier of the Legion of Honour. Mr. Ramas was a graduate of Arts et Metiers School of Paris, a professor at the French Foundry High School and in business was managing director of the Société Français Métallurgique "Griffin." For many years to come his portly figure and cheery personality will be sorely missed at international gatherings of foundrymen.

Company Reports

Electric Furnace Company, Limited.—Final dividend on the ordinary shares of 4½ per cent., making 7 per cent. for the year.

John Hetherington (Holdings), Limited.—Profit of £1,842 for the year to March 31, which reduces the debit balance carried forward to £152,361.

Metal Industries, Limited.—Fourth interim dividend for the year ended March 31 of 2½ per cent. on the "A" and "B" ordinary stock.

J. Stone & Company, Limited.—Trading profits, £196,044; net profit, £125,650; brought in, £99,050; dividend of 10 per cent. on the ordinary shares; carried forward, £125,660.

Park Gate Iron & Steel Company, Limited.—Gross profit, after providing for taxation, £112,312; brought in, £25,085; written off for depreciation, £40,000; dividend of 3 per cent., £44,201; to reserve, £25,000; carried forward, £28,196.

Ransomes & Rapier, Limited.—Profit, £11,322; disposable balance, after providing for all outgoings, depreciation, interest on debentures, fees, etc., £11,651; dividend of 6 per cent. on the preference shares, £686; dividend of 2½ per cent. on the ordinary shares, tax free, £4,012; to reserve, £5,000; carried forward, £1,953. Meeting, June 11.

Manganese Bronze & Brass Company, Limited.—Trading profit for 1935, before charging depreciation, £38,353; balance, after charging directors' fees, debenture interest and provision for debenture redemption, and transferring £15,000 to depreciation reserve and £5,000 to reserve for contingencies, £5,748; brought in, £821; dividend of 6 per cent. on the "A" and "B" preference shares, £4,838; carried forward, £1,732.

Peass & Partners, Limited.—Profit for year to March 31, £219,101; interest on 4 per cent. debenture stock, £16,000; provision for depreciation of plant and equipment, £34,320; reserve for depreciation of investments, £25,000; reserve for renewals and improvements, £30,000; additional provision for pensions, £10,000. Of the balance of £103,781, it is proposed to carry forward £27,640, leaving "available profits" which, under the scheme of arrangement, are to be applied as to two-thirds towards redemption of "A" and "B" 5 per cent. debenture stock and bank debenture and as to one-third towards repayment of credit notes, of £76,141. Meeting, May 29.

Contracts Open

Dublin, June 3.—Iron and steel stores, for the Great Southern Railways Company. The Stores Superintendent, General Stores Department, G.S. Railways, Inchicore, Dublin.

Dursley, June 4.—180 yds. of 3-in. spun cast-iron mains and 850 yds. of 1½-in. galvanised steam piping, for the Rural District Council. Mr. F. J. Smart, clerk, The Institution, Dursley, Glos. (Fee £1 1s., returnable.)

Forthcoming Events

MAY 30, 31 AND JUNE 1.

The Institute of Vitreous Enamellers:—Second Scottish Conference in Glasgow.

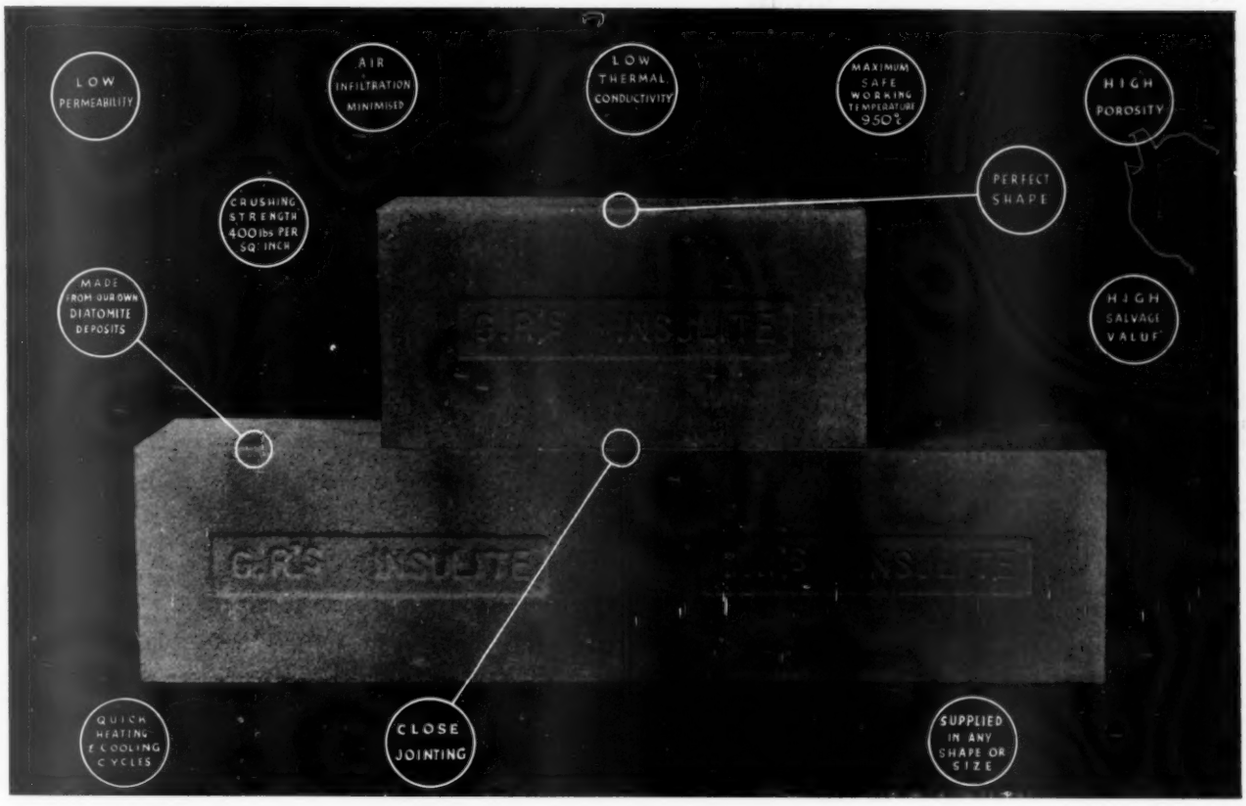
JUNE 8-13.

Twelfth International Congress of Acetylene, Oxy-Acetylene Welding and Allied Industries:—To be held in London.

Institute of British Foundrymen

JUNE 9-12.

Annual Conference in Scotland.



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Raw Material Markets

New business in the iron and steel markets during the past week has not amounted to any substantial tonnage. Most consumers are well covered over several months and, owing to the uncertainty with regard to prices after the end of June, are reluctant further to increase their commitments. Producers are demanding a premium for any contracts entailing delivery on and after July 1 in anticipation of increased quotations. Deliveries are still on a very heavy scale. Although the home trade is sufficient to maintain full activity at the producing plants, concern is felt regarding the pronounced decline in the number of export inquiries.

Pig-Iron

MIDDLESBROUGH.—Production of Cleveland foundry pig-iron has been increased slightly and one or two small parcels have been sold to consumers who had the most urgent needs. However, new business is still being held up by the shortage of supplies and arrears in deliveries under existing contracts have still to be cleared. Conditions are likely to remain in this state for a considerable period, for the output is now almost at the maximum for this area. It is almost certain that current prices will be raised by 5s. per ton for delivery after June 30, but, meanwhile, values are nominal, the official minima for No. 3 Cleveland G.M.B. being 70s. per ton in the Middlesbrough and Falkirk areas, 72s. on the North-East Coast, and 73s. on Clydeside, 1s. per ton less than these figures being charged for No. 4 foundry and No. 4 forge qualities, while No. 1 foundry is 2s. 6d. per ton more than No. 3.

Pressure for deliveries of hematite is very heavy and makers are unable to entertain new inquiries. Any iron that becomes available is immediately taken up in the home market and little export trade has been transacted. Current prices are likely to be increased by 5s. per ton in order to counteract the heavier costs of production, but deliveries are still being made at 77s. per ton for No. 1 East Coast hematite delivered on the North-East Coast and in Scotland.

LANCASHIRE.—Consumption of pig-iron is very heavy in this area and makers are experiencing considerable difficulty in complying with the demand for deliveries. For delivery to foundries in the Lancashire price zone up to the end of June, quotations are largely nominal on the basis of 78s. per ton for Derbyshire and Staffordshire brands of No. 3 foundry iron, with Northants at 76s. 6d., and Derbyshire forge iron at 73s. to 75s. There is a steady demand for hematite iron and, for delivery equal to Manchester, West Coast material is quoted at around 85s. 6d. per ton, East Coast from 84s. 6d. to 85s., with Scottish No. 3 foundry iron quoted in the region of 89s.

MIDLANDS.—The inquiry for supplies of Midland brands of ordinary-quality foundry pig-iron remains very heavy. Outputs have been fully disposed of until the end of June, when higher prices will come into operation. New business at the present time is almost negligible and the Association minimum values remain at 72s. 6d. for Northants No. 3 and 75s. for Derbyshire, Lincolnshire and North Staffordshire No. 3, delivered Birmingham and Black Country stations, with 11d. extra if delivered into works. The light-castings trade and other iron-founders continue to be well employed, while increasing activity in the building trade has resulted in a heavier demand from that source. Forge pig-iron is quoted at 5s. per ton below No. 3 foundry for the ironworks, while only 3s. discount is allowed to the foundries. Values of special irons, as used by the general engineering and jobbing trades, are very firm and are almost certain to be raised later on. Consumption of these irons is heavy. Low-phosphorus iron, including Scottish No. 3, is quoted at 92s. 6d. to 100s., medium-phosphorus 80s. to 87s. 6d., while refined pig-iron varies considerably from £6 10s. to £7 15s. per ton. It is thought likely that, owing to the competition for these irons, prices will be stabilised, but no official announcement has been made, as yet. Business in the hematite market is not brisk and prices, for deliveries up to the end of July, are £4 8s. 6d. for West Coast mixed numbers, £4 7s. 6d. East Coast No. 3 and £4 7s. for Welsh mixed numbers, delivered Midland stations, with 1s. 6d. per ton extra if delivered into works.

SCOTLAND.—Very few new orders for pig-iron have been placed during the past week, and sellers are unwilling to book forward contracts. Hematite and basic irons have both been sold well into the fourth quarter. Scottish foundry iron has an evenly balanced supply and demand. Fuel supplies are difficult to obtain, and are the cause of limiting the output of iron. At the present time there are in Scotland six furnaces making foundry iron, five making hematite, and three are engaged on basic iron. The official minimum price of 79s. for No. 3 foundry f.o.t. furnaces, with 2s. 6d. extra for No. 1, is still in force. The light-castings founders are active, but the shortage of Cleveland iron continues to limit operations. Values of No. 3 Cleveland iron are nominal and unaltered at 70s. f.o.t. Falkirk and 73s. f.o.t. Glasgow. Local steelworks are well employed and are taking up heavy tonnages of hematite and basic iron. Official prices for steel-making pig-iron remain at 77s. for East Coast, West Coast and Scottish hematite, with British and Indian basic at 72s. 6d. (less 5s. rebate), all f.o.t. steelworks.

Coke

The foundry-coke market maintains its firm appearance. It is suggested that prices may be raised still further. For delivery to Birmingham and district, best Durham cupola coke is quoted from 41s. 6d. to 43s., and Welsh coke is from 39s. to 50s. per ton.

Steel

Steady conditions rule in the steel market and, although new business is rather quiet, production is maintained at a high level, states the official report of the London Iron and Steel Exchange. It is expected that prices will be increased at the end of the half-year and transactions for the most part are limited to delivery before that date. In the semi-finished steel department the position is less stringent, but the output of the British works producing this class of material is passing immediately into consumption, and some works are behind with deliveries. Recent importations of Continental material, however, have created an easier situation, and the consuming industries are finding it less difficult to obtain the necessary supplies. Business in finished steel has been moderately active, and there has been some improvement in the volume of inquiry from overseas markets. The heavy steelworks are operating at capacity and can see their way to maintaining the present rate for some time to come. In spite of the lull in new business there are no signs of any diminution in the requirements of the home market.

Scrap

The demand for heavy melting scrap in the Cleveland market is increasing, but the delivered price is still 57s. 6d. per ton. There have been further imports of heavy foundry cast iron and machinery metal, but the prices remain at 62s. 6d. and 65s. respectively. The demand for all qualities of scrap has been maintained on the Midland market. Heavy melting steel receives numerous inquiries, and larger tonnages are available. Heavy steel in furnace sizes is at 52s. 6d. to 55s., while 52s. 6d. is offered for mixed iron and steel. Heavy machinery metal, in cupola sizes, is 70s., while there is a consistent demand for short, heavy steel, suitable for foundry work, at the same figure, delivered works. Firm conditions continue to prevail on the Scottish market. Heavy, mild-steel, melting scrap remains at 57s. 6d. per ton, with heavy basic, or heavy iron and steel scrap mixed, at 5s. less. First-class machinery cast-iron scrap, in pieces not exceeding 1 cwt., is at 69s. to 70s., while ordinary heavy cast iron, to the same specification, is 66s. to 67s. per ton, delivered f.o.t. consumers' works.

Metals

Copper.—Conditions in this market have been on the quiet side again this week and, although there has been a moderate amount of buying in this country, the market seems to have little incentive. In the United States there is only a small tonnage changing hands and the market is colourless. The political situation, although less tense, remains a drawback to international trading.

Daily market prices :—

Cash.—Thursday, £36 8s. 9d. to £36 10s.; Friday, £36 2s. 6d. to £36 3s. 9d.; Monday, £36 8s. 9d. to £36 10s.; Tuesday, £36 17s. 6d. to £36 18s. 9d.; Wednesday, £36 12s. 6d. to £36 13s. 9d.

Three Months.—Thursday, £36 13s. 9d. to £36 15s.; Friday, £36 8s. 9d. to £36 10s.; Monday, £36 13s. 9d. to £36 15s.; Tuesday, £37 2s. 6d. to £37 3s. 9d.; Wednesday, £36 17s. 6d. to £36 18s. 9d.

Tin.—Prices have again fallen, and it is generally accepted that the reason was the continuance of predictions of an increase in quotas for the third quarter. Buying has been only moderate in this country. The chief consuming industries in the United States have again been very active. At a meeting of the International Tin Committee in London on Tuesday it was decided, in view of the difficulties the Committee have felt in estimating the probable exports from Bolivia, that the quota to be fixed for the quarter July-September, 1936, would be considered at the meeting to be held in Paris on June 25.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £199 10s. to £199 15s.; Friday, £199 15s. to £200 5s.; Monday, £200 to £200 5s.; Tuesday, £201 5s. to £201 15s.; Wednesday, £201 to £201 10s.

Three Months.—Thursday, £194 15s. to £195; Friday, £194 to £194 10s.; Monday, £195 5s. to £195 10s.; Tuesday, £196 5s. to £196 10s.; Wednesday, £196 5s. to £196 10s.

Spelter.—Easy conditions have prevailed on this market, and little business has been in circulation. There has been an improved demand for galvanised products and the brassmakers are also active, but, otherwise, buying is at a low ebb. The Cartel negotiations are not developing as speedily as was looked for, and little stimulation is forthcoming to the market from this source. In the United States the market is featureless.

Official quotations were as follow :—

Ordinary.—Thursday, £14 6s. 3d.; Friday, £14 3s. 9d.; Monday, £14 5s.; Tuesday, £14 7s. 6d.; Wednesday, £14 8s. 9d.

Lead.—Consumption is well maintained, and steady buying has taken place, both in this country and on the Continent. The outlook, owing to the uncertainty of the international situation, remains obscure. The American Bureau of Metal Statistics reports that stocks of refined lead at the end of April were 221,000 tons, against 223,400 at the end of March. Production during the month was 38,100 tons against 35,200 in March.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £15 6s. 3d.; Friday, £15 8s. 9d.; Monday, £15 7s. 6d.; Tuesday, £15 12s. 6d.; Wednesday, £15 11s. 3d.

Catalogue Received

Centrifugal Fans. By publishing Catalogue No. S.F. 167, Davidson & Company, Limited, of Sirocco Engineering Works, Belfast, have done a real service to industry, because in it is shown by textual description and clear graphs the efficiency and other data germane to centrifugal fans having forward, radial and backward bladed fan wheels. Taking the foundry industry as typical, fans are used for collecting wood shavings and sawdust from the patternshop, ventilating the foundry, servicing the grinding machines in the fettling shop, blowing the cupola, moving atmospheres in various types of furnaces, providing forced draft for mould drying and core baking stoves, and many other applications. This catalogue provides an intelligent answer to the query as to which type to select for each duty. The brochure, however, goes a little farther than that, for it describes and illustrates machines the company have designed in each classification.

The immediate interest of the booklet, to our mind, is that it should enable readers to review their existing plant with the object of ascertaining whether they are operating what, in the light of recent experiments, are palpable misfits. The publication, which runs to 28 pages, is available to our readers on request.

TOR ROCK SAND

It is now possible to obtain from a deposit in the Midlands, a moulding sand possessing all the excellent characteristics of the Scottish Rock sands. This sand we have called Tor Rock Sand. It is well bonded, coarse in grain, and highly permeable.

The advantage this sand offers to iron founders in the Midlands and the South is obvious. Railway rates, which represent a high proportion of the cost of moulding sand when delivered are reduced considerably. Please write for full particulars and samples.

CHEMICAL ANALYSIS

Silica	86·8 %
Ferric Oxide	1·43%
Alumina	7·6 %
Lime	·22%
Magnesia	·18%
Titanic Oxide	·18%
Alkalies	1·8 %
Loss on ignition	1·6 %

MECHANICAL ANALYSIS

Very Coarse Sand (+ 1 mm)	16·5%
Coarse Sand (+·5 mm—1 mm)	16·0%
Medium Sand (+·25 mm—·5 mm)	11·0%
Fine Sand (+ ·1 mm—·25 mm)	30·0%
Silt Grade (+ ·01 mm—·1 mm)	7·0%
Clay Grade (—·01 mm)	19·5%

GENERAL REFRACTORIES Ltd.,

Genefax House, Sheffield.

Telephone: Sheffield 31113 (6 lines). Telegrams: "Genefax, Sheffield."

London Office:
Russell House,
Adelphi, W.C.2.
Telephone: Temple Bar 7351.
Telegrams:
"Genefax, Rand-London."

Scottish Office:
156, St. Vincent St.,
Glasgow.
Telephone: 5250.
Telegrams:
"Genefax, Glasgow."

South Wales Office:
11, Wind St.,
Swansea.
Telephone: 3680.
Telegrams:
"Genefax, Swansea."

MANUFACTURERS OF HEAT RESISTING AND HEAT INSULATING MATERIALS OF EVERY DESCRIPTION.

RAW MATERIALS—PRICE LIST

(Wednesday, May 27, 1936)

COPPER

	£ s. d.
Standard cash	36 12 6
Three months	36 17 6
Electrolytic	40 15 0
Tough	39 0 0
Best selected	39 15 0
Sheets	68 0 0
India	50 0 0
Wire bars	41 2 6
Ingot bars	41 2 6
H.C. wire rods	44 12 6
Off. av. cash, April	37 0 2½
Do., 3 mths., April	37 5 11½
Do., Sttlmnt., April	37 0 1½
Do., Electro, April	41 6 8½
Do., B.S., April	40 15 0
Do., wire bars, April	41 10 9
Solid drawn tubes	10½d.
Brazed tubes	10½d.
Wire	6½d.

BRASS

Solid drawn tubes	9½d.
Brazed tubes	11½d.
Rods, drawn	8¾d.
Rods, extd. or rlld.	5d.
Sheets to 10 w.g.	8d.
Wire	7¾d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5¾d.
Do. 4 × 3 Sheets	5¾d.

TIN

	£ s. d.
Standard cash	201 0 0
Three months	196 5 0
English	201 5 0
Bars	202 10 0
Straits	202 5 0
Australian (nom.)	201 0 0
Eastern	201 5 0
Banca	202 5 0
Off. av. cash, April	209 9 0¾
Do., 3 mths., April	203 16 3
Do., Sttlmt., April	209 8 0

SPELTER

	£ s. d.
Ordinary	14 8 9
Remelted	13 15 0
Hard	11 0 0
Electro 99.9	16 11 3
English	15 5 0
India	12 10 0
Zinc dust	19 10 0
Zinc ashes	4 5 0
Off. aver., April	15 5 1⅞
Aver. spot, April	15 3 7½

LEAD

	£ s. d.
Soft foreign ppt.	15 11 3
Empire (nom.)	16 7 6
English	17 10 0
Off. average, April	16 3 3¾
Average spot, April	16 1 11¼

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

Zinc sheets, English	24 10 0 to 25 0 0
Do., V.M. ex-whse.	24 10 0 to 25 0 0
Rods	26 15 0

ANTIMONY

English	66 10 0 to 67 10 0
Chinese, ex-whse.	56 0 0
Crude, c.i.f.	27 0 0

QUICKSILVER

Quicksilver	11 15 0 to 12 7 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 0 0 to £22 0 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 0 0
4/6% car.	21 15 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	33 10 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70% carbon-free	9½d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	6/3 to 6/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£11 5 0 to 11 15 0
76/80% packed	£12 5 0 to 12 15 0
76/80% export	(nom.) £10 5 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 1/16 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ¼ in.	3d. lb.
Do., under ¼ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£ s. d.	£ s. d.
South Wales—		
Heavy steel		3 5 0
Mixed iron and steel	3 0 0	to 3 1 6
Heavy cast iron	2 17 6	to 3 0 0
Good machinery	3 2 6	to 3 5 0
Cleveland—		
Heavy steel		2 17 6
Steel turnings		2 0 0
Heavy cast iron		3 2 6
Heavy machinery		3 5 0
Midlands—		
Light cast-iron scrap	2 12 6	to 2 15 0
Heavy wrought iron	3 7 6	to 3 10 0
Steel turnings		2 2 6
Scotland—		
Heavy steel		2 17 6
Ordinary cast iron	3 6 0	to 3 7 0
Engineers' turnings		2 2 6
Cast-iron borings	1 17 6	to 1 18 6
Wrot-iron piling		3 10 0
Heavy machinery	3 9 0	to 3 10 0

London—Merchants' buying prices, delivered yard.

Copper (clean)	29 0 0
Brass	19 0 0
Lead (less usual draft)	13 10 0
Tea lead	10 0 0
Zinc	9 0 0
New aluminium cuttings	74 0 0
Braziery copper	26 0 0
Gunmetal	27 0 0
Hollow pewter	150 0 0
Shaped black pewter	105 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	72/6
,, No. 3	70/-
,, at Falkirk	70/-
,, at Glasgow	73/-
,, No. 4	69/-
Forge No. 4	69/-
Hematite No. 1	77/-
Hematite M/Nos.	76/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	77/-
,, d/d Birm.	88/6
Malleable iron d/d Birm.	120/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	72/-
,, No. 3 fdry.	75/-
Northants forge	69/6
,, fdry. No. 3	72/6
,, fdry. No. 1	75/6
Derbyshire forge	72/-
,, fdry. No. 3	75/-
,, fdry No. 1	78/-
Scotland—	
Foundry, No. 1, f.o.t.	81/6
,, No. 3, f.o.t.	79/-
Hem. M/Nos. d/d	77/-
Sheffield (d/d district)—	
Derby forge	69/6
,, fdry. No. 3	72/6
Lincs forge	69/6
,, fdry. No. 3	72/6
W.C. hematite	90/-
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	78/-
Staffs fdry. No. 3	78/-
Northants fdry. No. 3	76/6
Cleveland fdry. No. 3	78/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	89/-
Clyde, No. 3	89/-
Monkland, No. 3	89/-
Summerlee, No. 3	89/-
Eglinton, No. 3	89/-
Gartsherrie, No. 3	89/-
Shotts, No. 3	89/-

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.)		10 2 6
Nut and bolt iron	8 10 0	to 9 0 0
Hoops	11 0 0	and up.
Marked bars (Staffs) f.o.t.		12 10 0
Gas strip	11 0 0	and up.
Bolts and nuts, ¾ in. × 4 in.	15 15 0	and up.
Steel—		
Plates, ship, etc.	8 15 0	to 8 17 6
Boiler plts.	9 5 0	to 9 7 6
Chequer plts.		10 7 6
Angles		8 7 6
Tees		9 7 6
Joists		8 15 0
Rounds and squares, 3 in. to 5½ in.		9 7 6
Rounds under 3 in. to ½ in. (Untested)		9 1 0
Flats—8 in. wide and over		8 12 6
,, under 8 in. and over 5 in.		8 17 6
Rails, heavy	8 5 0	to 8 10 0
Fishplates		12 10 0
Hoops (Staffs)		9 16 0
Black sheets, 24g. (4-t. lots)		11 10 0
Galv. cor. shts. (,,)		13 10 0
Galv. flat shts. (,,)		14 0 0
Galv. fencing wire, 8g. plain		15 0 0
Billets, soft	5 17 6	and up.
Billets, hard	6 17 6	to 7 2 6
Sheet bars	5 15 0	to 6 5 0
Tin bars	5 15 0	to 6 5 0

PHOSPHOR BRONZE

	Per lb. basis
Strip	10½d.
Sheet to 10 w.g.	11½d.
Wire	12½d.
Rods	11½d.
Tubes	14d.
Castings	12½d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	21.31
No. 2 foundry, Valley	19.50
No. 2 foundry, Birm.	15.50
Basic, Valley	19.00
Malleable, Valley	19.50
Grey forge, Valley	19.00
Ferro-mang. 80%, seaboard	75.00
O.-h. rails, h'y, at mill	36.37½
Billets	28.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.85
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.80
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.10
Plain wire	2.40
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 32/6
,, furnace	20/- to 22/6
Durham foundry	25/- to 26/-
,, furnace	22/6
Scotland, foundry	30/-
,, furnace	25/- to 26/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes 20×14 per box	18/9
,, 28×20 ,,	37/6
,, 20×10 ,,	27/-
,, 18¾×14 ,,	19/6
C.W. 20×14 ,,	15/9 to 16/3
,, 28×20 ,,	34/3
,, 20×10 ,,	23/-
,, 18¾×14 ,,	15/9 to 16/3

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£6 0 0 to £7 0 0
Bars-hammered, basis	£16 0 0 to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0 to £16 0 0
Blooms	£10 0 0 to £12 0 0
Keg steel	£30 0 0 to £31 0 0
Faggot steel	£18 0 0 to £23 0 0
Bars and rods dead soft, st'l	£10 0 0 to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

	£	s.	d.		
May 21 ..	36	8	9	inc.	3/9
,, 22 ..	36	2	6	dec.	6/3
,, 25 ..	36	8	9	inc.	6/3
,, 26 ..	36	17	6	,,	8/9
,, 27 ..	36	12	6	dec.	5/-

Electrolytic Copper

	£	s.	d.		
May 21 ..	40	10	0	No	change
,, 22 ..	40	5	0	dec.	5/-
,, 25 ..	40	5	0	No	change
,, 26 ..	41	0	0	inc.	15/-
,, 27 ..	40	15	0	dec.	5/-

Standard Tin (cash)

	£	s.	d.		
May 21 ..	199	10	0	inc.	25/-
,, 22 ..	199	15	0	,,	5/-
,, 25 ..	200	0	0	,,	5/-
,, 26 ..	201	5	0	,,	25/-
,, 27 ..	201	0	0	dec.	5/-

Tin (English ingots)

	£	s.	d.		
May 21 ..	199	15	0	inc.	30/-
,, 22 ..	200	0	0	,,	5/-
,, 25 ..	200	0	0	No	change
,, 26 ..	201	10	0	inc.	30/-
,, 27 ..	201	5	0	dec.	5/-

Spelter (ordinary)

	£	s.	d.		
May 21 ..	14	6	3	dec.	1/3
,, 22 ..	14	3	9	,,	2/6
,, 25 ..	14	5	0	inc.	1/3
,, 26 ..	14	7	6	,,	2/6
,, 27 ..	14	8	9	,,	1/3

Spelter (Electro, 99.9 per cent.)

	£	s.	d.		
May 21 ..	16	10	0	No	change
,, 22 ..	16	7	6	dec.	2/6
,, 25 ..	16	8	9	inc.	1/3
,, 26 ..	16	11	3	,,	2/6
,, 27 ..	16	11	3	No	change

Lead (soft foreign, prompt)

	£	s.	d.		
May 21 ..	15	6	3	dec.	1/3
,, 22 ..	15	8	9	inc.	2/6
,, 25 ..	15	7	6	dec.	1/3
,, 26 ..	15	12	6	inc.	5/-
,, 27 ..	15	11	3	dec.	1/3

Lead (English)

	£	s.	d.		
May 21 ..	17	10	0	No	change
,, 22 ..	17	10	0	,,	,,
,, 25 ..	17	10	0	,,	,,
,, 26 ..	17	10	0	,,	,,
,, 27 ..	17	10	0	,,	,,

AVERAGE MONTHLY PRICES OF RUBIO ORE (MIDDLESBROUGH).

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1897	0 15 3	0 15 6	0 15 3	0 15 0	0 14 0	0 14 3	0 14 3	0 14 0	0 14 0	0 15 0	0 14 3	0 15 3	0 14 8
1898	0 15 0	0 14 4	0 14 9	0 14 6	0 15 0	0 15 0	0 14 0	0 14 0	0 14 0	0 14 9	0 15 0	0 14 9	0 14 7
1899	0 15 0	0 15 3	0 15 6	0 15 6	0 15 9	0 16 0	0 17 6	0 18 0	0 17 9	0 18 0	0 19 0	1 0 0	0 16 11½
1900	1 1 0	1 0 6	1 1 0	1 0 9	1 1 0	1 1 0	1 1 3	1 1 6	1 1 3	1 1 3	1 0 0	0 18 0	1 0 8½
1901	0 17 6	0 16 0	0 15 0	0 14 6	0 15 6	0 15 9	0 14 9	0 15 3	0 15 9	0 15 9	0 15 9	0 15 9	0 15 7½
1902	0 15 6	0 15 0	0 16 0	0 16 0	0 15 6	0 15 3	0 15 6	0 16 0	0 16 0	0 15 9	0 15 9	0 15 6	0 15 8½
1903	0 15 6	0 16 0	0 16 6	0 16 3	0 16 3	0 16 10	0 15 9	0 15 6	0 15 6	0 14 9	0 14 9	0 15 1	0 15 8
1904	0 14 9	0 15 3	0 15 1	0 15 4	0 15 3	0 15 0	0 14 5	0 14 6	0 14 6	0 14 6	0 14 6	0 14 7	0 14 9½
1905	0 15 3	0 15 6	0 15 0	0 15 3	0 15 6	0 15 6	0 15 6	0 15 6	0 16 6	0 18 6	0 18 9	0 18 9	0 16 2½
1906	1 0 0	1 1 6	1 0 0	1 0 0	0 19 6	1 0 0	0 19 6	0 19 4	1 0 6	1 1 6	1 1 9	1 3 6	1 0 7
1907	1 3 6	1 2 6	1 2 6	1 2 0	1 1 6	1 2 3	1 2 3	1 0 0	1 1 0	0 19 0	0 18 9	0 17 6	1 1 2½
1908	0 16 6	0 15 0	0 15 6	0 15 6	0 15 3	0 15 0	0 15 0	0 14 9	0 15 0	0 16 0	0 16 0	0 16 0	0 15 8½
1909	0 15 9	0 16 3	0 16 0	0 16 0	0 16 3	0 16 6	0 16 0	0 16 0	0 17 0	0 17 0	0 17 6	0 17 6	0 16 6
1910	1 0 4	1 0 9	1 0 9	1 0 9	1 0 9	1 0 9	1 0 9	1 0 3	1 0 3	1 0 6½	1 1 3	1 1 3	1 0 9½
1911	1 2 2½	1 2 6	1 2 6	1 1 11½	1 11½	1 0 19 6	1 0 19 0	1 0 19 0	1 0 19 1½	1 0 19 6	1 1 0 0½	1 1 6½	1 0 7½
1912	1 2 3	1 2 6	1 2 6	1 1 11½	1 1 6	1 1 6	1 1 6	1 2 3	1 2 6	1 3 0	1 3 0	1 2 11	1 2 2½
1913	1 2 9	1 2 2	1 1 7½	1 1 6	1 0 8½	1 0 0	1 0 0	1 0 0	0 19 10½	0 19 1½	0 19 0	0 19 0	1 0 5½
1914	0 18 7½	0 18 0	0 18 0	0 17 9	0 17 6	0 17 6	0 17 1½	0 19 7½	0 18 11½	0 17 10½	0 18 7½	1 1 0½	0 18 5½
1915	1 7 7½	1 8 6	1 9 3	1 10 2½	1 8 6	1 6 4	1 5 10½	1 6 0	1 6 10½	1 10 8½	1 13 0	1 17 10	1 9 1½
1916	1 18 6	2 0 1½	2 2 6½	2 0 6½	1 15 0	1 16 3	1 18 0	1 18 0	1 18 0	—	—	—	—
1917	} Price Fixed												
1918													
1919	—	—	—	—	2 5 7½	2 14 4½	2 16 4½	2 14 0	2 13 4½	2 13 0	2 12 7½	2 11 9	—
1920	2 17 0	3 7 9	2 15 6	3 6 7	3 0 0	2 15 0	2 14 0	2 9 9	2 7 6	2 11 0	2 12 3	2 10 0	2 15 0
1921	2 1 0	2 0 1½	1 18 3	1 17 6	1 17 6	1 17 6	1 17 6	1 5 0	1 8 9½	1 7 9	1 7 0	1 7 0	1 13 8½
1922	1 6 7½	1 5 10½	1 6 11	1 7 0	1 7 0	1 7 0	1 5 3	1 4 9½	1 4 2½	1 3 3½	1 2 6	1 2 3	1 5 2½
1923	1 2 9½	1 4 6½	1 5 2	1 4 8½	1 4 6	1 4 0	1 3 6	1 3 0	1 3 0	1 3 0	1 3 2½	1 4 9	1 3 10½
1924	1 4 2½	1 4 0	1 4 0	1 3 7½	1 3 8½	1 3 6	1 2 11	1 2 6	1 2 1½	1 1 7½	1 2 3	1 2 6	1 3 1
1925	1 2 6	1 2 1½	1 2 0	1 2 0	1 2 0	1 1 6	1 0 6	1 0 0	1 0 0	1 0 0	1 0 3	1 0 10½	1 1 1½
1926	1 1 1½	1 1 6	1 1 6	1 1 3½	1 1 3	1 1 5½	1 1 6	1 1 6	1 1 0	1 1 6	1 1 6	—	1 1 4½
1927	1 2 1½	1 2 3	1 2 1½	1 2 0	1 2 0	1 2 0	1 1 7½	1 1 0	1 1 0	1 1 0	1 1 0	1 1 0	1 1 7½
1928	1 1 0	1 1 1½	1 1 11	1 2 4½	1 2 6	1 2 6	1 2 6	1 2 6	1 2 6	1 2 6	1 2 6	1 2 6	1 2 2½
1929	1 2 6	1 2 6½	1 2 11½	1 3 0	1 3 0	1 3 2½	1 4 0	1 4 8½	1 4 7½	1 4 6	1 4 6	1 4 3	1 3 7½
1930	1 3 3½	1 2 6	1 1 9	1 1 6	1 0 10½	1 0 0	1 0 0	0 19 6	0 19 0	0 17 4½	0 16 4½	0 19 10½	
1931	0 16 1½	0 16 0	0 16 0	0 15 11½	0 15 4½	0 15 0½	0 14 10½	0 14 3½	0 14 6	0 16 8½	0 17 0½	0 16 6	0 15 9
1932	0 16 6	0 16 6	0 16 3	0 15 6	0 15 4½	0 15 0	0 14 11	0 14 8½	0 14 6	0 14 6	0 14 9	0 15 1	0 15 3½
1933	0 15 6	0 15 3	0 15 3	0 15 3	0 15 3	0 15 6	0 15 6	0 15 6	0 15 6	0 15 11½	0 16 6	0 16 6	0 15 7½
1934	0 16 6	0 17 6	0 16 9	0 16 6½	0 16 8½	0 16 9½	0 17 0	0 17 0	0 17 0	0 17 0	0 17 0	0 17 0	0 16 10½
1935	0 17 0	0 17 4½	0 17 6	0 17 6	0 17 6	0 17 6	0 17 6	0 17 6	0 17 6	0 17 7½	0 18 0	0 18 0	0 17 6½
1936	0 18 0	0 18 3½	0 18 6½	0 18 9	—	—	—	—	—	—	—	—	—

WILLIAM JACKS & COMPANY,

WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

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